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Curriculum Guideline

Science

Intermediate and Senior Divisions

1989

Part 10

Applied Physics and Technological Science

Grade 12, General Level

Contents

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Introduction

The Parts of the Guideline

This document is Part 10 of a fifteen-part curriculum guideline that outlines the science program for the Intermediate and Senior Divisions in Ontario schools and describes the science courses that can be offered (see the list of courses and their course codes in Appendix A). The term *guideline* refers to the entire set of fifteen parts.

This part must be read and implemented in conjunction with Part 1, *Program Outline and Policy*. When implementing the courses that are described in this document, teachers are to incorporate the many policies and features outlined in Part 1, which will enable them to interpret the overall intent and expectations of the Ministry of Education in the science program. The table of contents for Part 1 is given in Appendix B at the end of this document so that the reader may have ready access to the list of chapters and topics therein.

The provincial science program for the Intermediate and Senior Divisions comprises the courses described in Parts 2 to 15. These come under the framework and policy set forth in Part 1. The entire science guideline consists of the following fifteen parts:

Part 1: Program Outline and Policy
Part 2: Science, Grades 7 and 8
Part 3: Science, Grades 9 and 10, General Level
Part 4: Science, Grades 9 and 10, Advanced Level
Part 5: Science, Grades 9 and 10, Basic Level
Part 6: Science, Grades 11 and 12, Basic Level
Part 7: Environmental Science, Grades 10 to 12, General Level
Part 8: Environmental Science, Grades 10 and 12, Advanced Level
Part 9: Applied Biology and Applied Chemistry, Grade 11, General Level
Part 10: Applied Physics and Technological Science, Grade 12, General Level
Part 11: Geology, Grade 12, General and Advanced Levels
Part 12: Biology, Grade 11, Advanced Level, and the OAC
Part 13: Chemistry, Grade 11, Advanced Level, and the OAC
Part 14: Physics, Grade 12, Advanced Level, and the OAC
Part 15: Science in Society, OAC

The chart on the next page indicates the twenty-eight science guideline courses that may be offered in Grades 7 to 12 and at the OAC level.

Policies and Features That Apply Across the Science Program

Part 1 of the guideline specifies a great number of policies and features that are to be integrated into the design of the science program in the Intermediate and Senior Divisions. There are too many of them to describe in full in each of Parts 2 to 15, but the following points will give the reader some idea of the scope that is involved. They include:

- information about the science credits that are required for the earning of the Ontario Secondary School Diploma;
- a list of science courses that are prerequisite to other science courses;
- the policy regarding mandatory student activities in the science laboratory;
- a list of the aims of the science curriculum and the various emphases that may be used to blend these aims with scientific content;
- policy governing time allocations for units of study and the order in which core and optional units may be taught;
- stipulations about locally designed units;
- suggestions about preferred routes that students might take through the science program in a secondary school;
- recommendations related to exceptional students, individualized instruction, life-management skills, career awareness, the role and evaluation of language in science courses, and a balanced perspective on the role of both girls and boys in science;
- recommendations on the introduction and handling of sensitive issues;
- specific suggestions about resources for the teaching of science;
- ideas about different modes of delivering science courses, including the co-operative education mode;
- policy pertaining to the significant role to be played by measurement and metric units in science courses;
- stipulations related to the treatment of symbols, significant digits, and mathematical problem solving;

Authorized Science Guideline Courses, Intermediate and Senior Divisions

	Basic Level	**General Level**	**Advanced Level**
Grade 7	Science		
Grade 8	Science		
Grade 9	Science (SNC1B)	Science (SNC1G)	Science (SNC1A)
Grade 10	Science (SNC2B)	Science (SNC2G) Environmental Science (SEN2G)	Science (SNC2A) Environmental Science (SEN2A)
Grade 11	Science (SNC3B)	Applied Biology (SBA3G) Applied Chemistry (SCA3G) Environmental Science (SEN3G)	Biology (SBI3A) Chemistry (SCH3A)
Grade 12	Science (SNC4B)	Environmental Science (SEN4G) Geology (SGE4G) Applied Physics (SPA4G) Technological Science (STE4G)	Environmental Science (SEN4A) Geology (SGE4A)* Physics (SPH4A)
OACs			Biology (SBI0A) *Prerequisite* – Biology (SBI3A) Chemistry (SCH0A) *Prerequisite* – Chemistry (SCH3A) Physics (SPH0A) *Prerequisite* – Physics (SPH4A) Science in Society (SSO0A) *Prerequisite – One of:* Biology (SBI3A) Chemistry (SCH3A) Environmental Science (SEN4A) Geology (SGE4A)* Physics (SPH4A)

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*Since the Grade 12 advanced-level geology course described in the guideline (see Part 11) may be taught under the aegis of a geography department as Geology (GGE4A) – note the course-code change – then either Geology (SGE4A) or Geology (GGE4A) may count as a prerequisite to Science in Society (SSO0A).

- recommendations concerning the roles to be played by calculators and computers in science courses;
- specific directions about safety;
- policy and principles pertaining to the evaluation of student achievement;
- policy regarding differences in the treatment of science courses at the three levels of difficulty;
- many suggestions about implementing the science program.

It cannot be emphasized strongly enough that teachers of science must integrate the policy and recommendations outlined in Part 1 with the teaching of science and cannot simply rely on the course descriptions given in Parts 2 to 15 of the guideline.

The Science Curriculum Continuum

By the time students have reached the Senior Division they will have experienced first a *unified* approach in the Primary and Junior Divisions, in which science is related to a number of other subject areas, and then a *diversified* approach to a mosaic of science disciplines – biology, chemistry, physics, and environmental science – in the Intermediate Division. In the Senior Division they are provided with a *specialized* approach, in which the science courses deal with a single discipline at a time.

Although these approaches – unified, diversified, and specialized – provide different ways of dealing with the subject, the intention is to ensure that there is a continuum throughout the years. The Grade 12 Applied Physics and Technological Science courses at the general level build on the physical science units of the courses in the Intermediate years.

In all science courses the core units and the prescribed number of optional units, if any, are to be included. The time allocation for each unit of study should act as a guide in helping teachers devote a proportionate amount of time to each of the units in a course. This is important in view of the continuum from one course to another and to postsecondary science programs.

Compulsory and Prerequisite Courses

In the secondary school program two science courses are required among the compulsory subjects required for the earning of the Ontario Secondary School Diploma. It is, therefore, anticipated that most of the students who enrol in the Senior Division Applied Physics or Technological Science courses will have taken Grade 9 and 10 science, also at the general level.

Curriculum Emphases

It is recommended that teachers organize each of the courses described in this document around a particular curriculum emphasis or set of emphases. Such emphases give the curriculum a special focus that can be introduced in addition to the content and processes outlined in the courses. This approach is discussed in subsection 3.4, "Curriculum Emphases – Blending Curriculum Aims With Content", of Part 1 of the science guideline. A list of emphases is given in table 2 of that subsection. These emphases will enhance the development of the science courses described in this document. A particular emphasis that is stressed throughout an entire course or for one or more units at a time needs to be highlighted so that it becomes a focal or an integrating theme.

Student Activities

In each unit of study there is a section entitled "Student Activities". This section indicates the mandatory *laboratory* activities required of students. Teachers may substitute *equivalent* activities where appropriate. Those activities that are actually to be performed by students themselves are marked with asterisks. If time and circumstances permit, the teacher should encourage students to do some or all of the unmarked activities as well. However, such activities may be demonstrated by a student or the teacher or may be discussed in conjunction with a textbook, a film, a computer program, or another learning material used as a resource. In any event, the scientific concepts and principles related to such unmarked activities and identified in the objectives of the unit of study shall be considered to be part of the prescribed course.

Generally, the best approach to the teaching of science is to ensure that the content develops directly from related student activities. In each unit of study the skills and processes of scientific work should be presented as the central component, from which the subject matter, applications, and implications emerge.

Safety

Safety awareness must be developed in all science students. Constant attention to accident prevention is to be stressed in all student activities and teacher demonstrations in the laboratory. Section 9, "Safety", in Part 1 of the science guideline contains the following comprehensive subsections:

- Safety in the Laboratory
- Some Recommended Safety Procedures
- Animal Care in Science Courses
- The Safe Use of Plants

In each unit of study the section entitled "Safety Considerations" acts as a reminder of some of the safety features that pertain to the unit in question. General reference, however, should constantly be made to the safety section in Part 1. In addition, schools must always remain on the alert in regard to safety and maintain an up-to-date safety-awareness program. For example, this guideline does not outline all precautions regarding field trips.

Sensitive Issues

The curriculum outlined in this science guideline places a distinct emphasis on the science-technology-society connection. For this reason scientific applications and societal implications are mandatory components of each unit of study. In addition, Part 1 of this guideline underlines the need to incorporate morals/values education into science courses. Undoubtedly, this will give rise to the discussion of some sensitive issues.

Such discussions are important. Generally, they should be focused and should provide an open forum for the expression of different viewpoints. In this regard teachers of science are urged to familiarize themselves with section 10, "Values in Science Education", of Part 1 of the guideline and to pay particular attention to the principles to be observed when dealing with sensitive issues in the science curriculum. These principles are mentioned in subsection 10.2 of Part 1.

Locally Designed Units

Among the optional units in each of the courses described in this document is one entitled "Locally Designed Unit" (LDU). These units are included to allow teachers, at their discretion, to introduce an appropriate new area of study not described in the guideline, to expand on previous units or topics by adding new work, or to use the time allocated to the LDUs to extend the time allocations for the core units. (See also Part 1, subsection 5.5.)

Evaluation of Student Achievement

In each unit of study described in the courses outlined in this document, the section entitled "Evaluation of Student Achievement" specifies certain items that must be included in the students' term marks (exclusive of formal examinations) when their achievement is evaluated. In most units teachers are required to evaluate students' activities and related laboratory reports. However, the proportion of the mark assigned will vary from one teacher to another. In order that the experimental component of science be emphasized, the overall mark for an entire science course must include at least 15 per cent for the evaluation of student achievement in laboratory skills and reports.

Cross References

In the descriptions of each unit of study in the courses outlined in this document, cross references are provided in parentheses. These are included to provide some examples of the relationships that exist among the parts of the unit.

Particular Features of the Applied Physics and Technological Science Courses

Units of Study and Their Time Allocations

The following charts provide an overview of the units of study in this course and indicate the time to be allocated to each unit. Subsection 5.4 of Part 1, *Program Outline and Policy*, states, "The time allocations are to be considered as fairly rigid for advanced-level courses, slightly less so for general-level courses, and flexible for basic-level courses." In keeping with this policy, teachers are permitted to shorten any unit in this guideline by two hours and transfer that time to one of the other units. It is hoped that teachers will elect to do this to cover some units or portions of units in more depth than is indicated by the guideline. The units selected for this treatment should be determined by the ability and interest of a particular class.

Applied Physics, Grade 12, General Level (SPA4G)

Units of Study		Time Allocations
Core		
1. Sound		18 h
2. Light and Colour		18 h
3. Heat		18 h
4. Electrical Energy		18 h
5. Motion		18 h
		90 h
Optional		
Two of:		
1. Fluids	10 h	20 h
2. Nuclear Energy	10 h	
3. Properties of Solids	10 h	
4. Locally Designed Unit	10 h	
		110 h

Technological Science, Grade 12, General Level (STE4G)

Units of Study		Time Allocations
Core		
1. Chemical Language and Calculations		16 h
2. Thermochemistry		16 h
3. Chemical Analysis		17 h
4. Kinematics		16 h
5. Statics		12 h
6. Kinetics		21 h
		98 h
Optional		
One of:		
1. Fluids	12 h	12 h
2. Machines	12 h	
3. Materials	12 h	
4. Locally Designed Unit	12 h	
		110 h

Some Teaching Suggestions

Applied Physics

This course is the first course in physics available to secondary school students at the general level. For the majority of the students who elect it, it will be the only physics course that they will take as part of their formal education. The main aims of this course are to enable these students to understand better the world about them and to improve their skills in observing, reasoning, communicating, researching, and co-operating. If these aims are to be achieved, it is essential that a number of practical or "hands-on" activities be incorporated into every unit. Teachers should also make students aware of the careers that are related to the various topics they are studying and draw students' attention to practical applications of the concepts involved. The aims of science listed in Part 1 that are especially appropriate for this course and the students likely to take it are as follows:

7. an appreciation of technology as the application of scientific knowledge and principles
8. an ability to locate and retrieve scientific information
9. an awareness of the career possibilities in the field of science and technology
10. an awareness of how the knowledge of science enhances personal life management

A secondary aim of this course is to prepare students for further courses in science and technology. For example, this course should provide a useful background for those students pursuing a technician program at the postsecondary level. Students who wish to pursue a technology program are advised to enrol in Technological Science as well.

Fundamental physical and mathematical concepts have been limited to those that are essential and applicable to the units that have been selected for study. Teachers are urged to avoid putting undue emphasis on mathematics, thereby increasing students' frustration and decreasing their motivation. More advanced concepts in physics and more rigorous mathematics are found in the Grade 12 Technological Science course.

It is intended that the overall evaluation of student achievement reflect the primary emphasis of practical laboratory work and include other components as indicated in Part 1. In this course 50 per cent of the evaluation for each unit is specified. The balance of the evaluation for the unit is to be established by the teacher. Teachers are urged to evaluate students' attitudes and work habits, such as their ability to work co-operatively in a group, their ability to stick to a task, and their ability to listen carefully and politely to someone else.

Motivation is the key to successful teaching in this course. More effort is required at this level than with advanced-level courses to show students the relevance of the material they are studying and to catch their interest. For this reason one or more suggestions for introducing the unit are given at the beginning of each unit. Numerous teaching suggestions are also provided at the beginning of each unit. Teachers should not view these as being prescriptive but rather as a bank of ideas from which they can draw.

The optional unit entitled "Locally Designed Unit" may be used to introduce a new area of physics not described in the guideline or to include new work that expands on previous topics in the course. If new topics are introduced in a locally designed unit, care should be taken to avoid physics topics that are included in units of the Technological Science course, unless students are unlikely to take that course.

Technological Science

This course is designed to enable students at the general level to have an opportunity to develop skills in various applications of technology and to prepare them for technological diploma courses offered at the colleges of applied arts and technology.

Since this course is provided as a bridge between the general-level secondary school science courses and the technology programs at the community colleges, it emphasizes abstract reasoning and the ability to handle complex variables. It also emphasizes a practical and applied approach to science so that students will have opportunities to improve their skills in the areas of data collection, organization, interpretation, and communication.

The course is designed to build on the knowledge and skills that students may have acquired in the Applied Chemistry and Applied Physics courses. Teachers should be familiar with the content of these courses so that this course will complement previous studies.

The optional unit entitled "Locally Designed Unit" may be used to introduce a new area of technology not described in the guideline, to include new work that expands on previous topics in the course, to extend the time allocations for the core units by an additional twelve hours, or for research into science and technology projects for science fairs.

Subsection 8.2 of Part 1 of this guideline contains a list of metric units with which students are expected to be familiar by the end of Grade 10. In Senior Division courses the list of metric units with which science students work will naturally expand. Metric units are preferred and should always be indicated; however, in some areas non-metric units may still be in general use and should be indicated.

Applied Physics, Grade 12, General Level (SPA4G)

Core Units

Sound
Light and Colour
Heat
Electrical Energy
Motion

(90 hours)

Optional Units

Fluids
Nuclear Energy
Properties of Solids
Locally Designed Unit

(20 hours)

Core Unit 1

Sound

Time: 18 hours

Our ears give us the ability to receive and process sound. They are extremely sensitive, able to detect minute pressure variations. Amazingly they also tolerate an extremely large range in pressure variation. Sound is very important in our ability to communicate and learn as well as enjoy all aspects of our lives.

Music plays a significant role in the lives of many people, and a study of the characteristics of sound is therefore a very relevant study. High-intensity sounds or even moderate levels for sustained periods of time can have a negative effect not only on the ear but also on the general well-being of a person. A variety of careers are involved with regulating and shaping the sounds that we hear.

This unit may be divided into topics such as the following:

- Sound sources and the human voice
- Sound: a longitudinal wave
- Characteristics of sound
- Sound detection and the human ear
- Special effects with sound (e.g., interference, resonance, reverberation, Doppler effect)

A record player or tape recorder playing a current "hit song" and connected to an oscilloscope should interest students. This could lead to a preliminary examination of the pattern that students' own voices leave on the screen when amplified and connected to the oscilloscope. Computer hardware and software are available to make it possible to print out a hard copy of a student's voice pattern. A discussion of movies or TV programs that students have seen may cause someone to recall a situation in which a computer would permit a specific lock to be opened only if it recognized a specific voice pattern.

A discussion of careers in which an understanding of these wave patterns is important could be initiated. Sound technicians for rock bands or for radio and TV stations, designers of synthesizers, and individuals responsible for special musical effects would all have to have some degree of familiarity with such wave forms.

Finally, the pattern produced by a pure tone (e.g., from a tuning fork or a signal generator) could be used to show that in its simplest form sound can be represented as a simple wave. An understanding of these simple waves is essential for an understanding of the more complex sound waves produced by the objects around us.

1. Objectives

Attitudes. Students will be encouraged to develop:

a) a curiosity about how we hear sound (4b, 5b);
b) a curiosity about how sounds are produced;
c) a concern for the damage that can be caused by any loud sound, such as loud music or noise in the workplace (5b-5d);
d) an appreciation for how certain structures are designed to enhance or suppress sound (4d, 4f, 4i, 5d).

Skills. Students will have the opportunity to develop skill in:

a) inferring causes for changes in the characteristics of the wave pattern on an oscilloscope that is monitoring sound (3d);
b) drawing diagrams to illustrate how an oscilloscope pattern changes when the frequency, intensity, or quality of a sound is changed (3d);
c) drawing diagrams that illustrate the characteristics of longitudinal and transverse waves (3b);
d) recording and organizing observations in a table or chart (3a, 3f, 3i);
e) interpreting observations to develop conclusions about (i) how the lack of a medium affects the transmission of sound (3b); (ii) how the tension, length, and diameter of a string affect the frequency of a stringed instrument (3f); (iii) how the properties of a surface affect the reflection of sound (3j);
f) manipulating equipment such as stop watches, pendulums, tuning forks, signal generators, amplifiers, oscilloscopes, and resonating air columns while investigating the characteristics and behaviour of sounds and vibration (3a, 3d, 3e, 3g);
g) determining the audible frequency range for another person, given a signal generator and an amplifier.

Knowledge. Students will be expected to:

a) describe the cause of any sound;
b) state the factors that affect the frequency of a pendulum;
c) describe the difference between a transverse and a longitudinal wave and correctly label a diagram of each;
d) illustrate the difference between constructive and destructive interference, using sketches;

e) give evidence that a medium is required for the transmission of sound;
f) label the parts of the ear and describe how it converts sound to a nerve impulse;
g) describe factors that can contribute to hearing loss and identify how to reduce their effects;
h) identify the wave characteristics that determine the pitch, loudness, and quality of a sound;
i) calculate the wave length of a sound, given its speed and frequency and using $v = f$;
j) describe an example of sound interference (2g);
k) describe how the reflection of sound may be illustrated;
l) describe techniques that can be used in the home and in industry to reduce reflections of sound;
m) describe examples of resonance;
n) state the speed of sound and describe the effect of temperature on the speed of sound;
o) state the speed range of human hearing and describe the application of infrasonic and ultrasonic sound waves.

2. Some Teaching Suggestions

a) By pressing the end of a sounding tuning fork to a cheek bone while placing a hand over the ear on the opposite side of the head, students can experience, in a simple but interesting fashion, the conduction of sound through the bones of the head.
b) To show students that sound is a pressure wave and that energy is transmitted by the movement of the wave and not by the air itself, the teacher can place a soap bubble on the end of a trumpet or other similar instrument. The bubble will remain intact while the trumpet is played.
c) Sound can be transmitted through air, water, and a solid such as a desk top or a metal bar to show that different media will conduct sound. If a vacuum pump and a bell jar are available, students can be shown that sound cannot be transmitted without a medium.
d) Computer software is available to illustrate a longitudinal wave by means of animation.
e) A light stroboscope adjusted to the correct frequency can be used to create the illusion that the tines of a low-frequency (e.g., 128 Hz) tuning fork are vibrating in slow motion.
f) An unmounted speaker connected to a tape recorder or record player will produce poor-quality sound. The same speaker placed in an opening just large enough for it in a sheet of plywood will produce dramatically improved sound. This effective demonstration of interference of sound could easily lead to a discussion or a research assignment on speaker design.
g) A long cardboard tube (of the type on which carpets are rolled for shipment) placed over a properly adjusted Meeker Bunsen burner gives an impressive demonstration of resonance. (Teachers should be careful not to ignite the tube.) If a slightly larger tube is slid over the original tube so that the length of the air column can be changed, the basic principle of a trombone can be demonstrated.
h) The inhaling of helium gas can change the pitch of a person's voice because it changes the speed of sound and thus the resonant frequency of the larynx.
i) Reverberation and the reverberation time of a room can be demonstrated by recording a hand clap in a room at a high recording speed and then playing it back at a slow speed.
j) A student who owns a guitar could be asked to illustrate how beats can be used to tune the guitar.
k) A student who owns an electronic keyboard or synthesizer could use it to illustrate many of the characteristics of sound. Similarly, most computers have considerable sound-synthesizing ability. Some students may wish to take this on as a special project and prepare a demonstration for the class.
l) Students can form a band that uses pop bottles filled to different levels so that each note in an octave can be produced by blowing across the appropriate bottle.
m) Ripple tanks can be used to provide a visual illustration of how sound waves (and therefore sound) can bend around a corner, interfere destructively in one location and constructively in another, and reflect from various-shaped surfaces.
n) This unit lends itself to the setting-up of a number of activity centres around the room. Students can be assigned to various activities and then rotate through all of them over a span of several periods.
o) If this unit is taught first, teachers should be sure to instruct students on how to prepare their reports on laboratory activities. As students progress through the course, they should be given more and more responsibility for organizing their observations and reporting their results.
p) A team of students with access to a video camera could visit a local hospital to prepare a short videotape on the use of ultrasound in diagnosing medical problems.
q) A manager or salesperson from a store specializing in the sale of high-quality stereo equipment could be invited to address the class on the criteria to use when purchasing a stereo system.
r) A police officer could be invited to explain how a radar system to catch speeders relies on the Doppler effect.
s) Some teachers may wish to consider teaching this unit in parallel with the unit on light to illustrate the similarity and difference in behaviour between light and sound.

3. Student Activities

Students are to:

- *a) determine the frequency of a vibrating pendulum and the effect that the mass of the bob, the amplitude or vibration, and the length of the pendulum have on its frequency;
- *b) use a Slinky to produce transverse and longitudinal waves and recognize the difference between these two types of waves;
- *c) investigate constructive and destructive interference, using a Slinky or another medium in which waves can readily be produced;
- *d) determine, using an oscilloscope, the effect on the sound wave of variations in pitch, loudness, and quality of sound.

A minimum of three of the remaining activities should be done. Students are to:

- e) determine the speed of sound in air;
- f) investigate, qualitatively, using a guitar or other stringed instrument, the factors that affect the frequency of a stretched string;
- g) investigate mechanical resonance, using an apparatus such as pendulums of different lengths attached to a piece of wood that is in turn attached to fixed stands by means of string;
- h) investigate acoustical resonance, using tuning forks on mounted resonance boxes;
- i) investigate beats (a special interference effect), using tuning forks on mounted resonance boxes;
- j) investigate resonance in air columns (this should be a semi-quantitative investigation in which students come to realize that a number of different lengths of column will resonate at a specific frequency and that the higher the frequency the shorter the first resonant length will be and the closer the resonant lengths will be together);
- k) investigate reflection and absorption of sound, using different surfaces and materials;
- l) investigate interference of sound.

4. Applications

- a) The flight of supersonic aircraft has to be restricted to specified flight corridors to prevent damage to buildings by the pressure wave called a *sonic boom*.
- b) Ultrasonic waves are used in diagnostic medicine, non-destructive testing of materials, cleaning, sterilizing, burglar alarms, and insect control.
- c) Sound of high frequency and intensity can cause structural damage to materials.
- d) Sound suppression, abatement, enhancement, and reflection are considerations in the design of structures, buildings, and theatres.
- e) A depth-determining device called *sonar* is used on military and commercial ships, fishing boats, and pleasure craft.
- f) A knowledge of sound interference is applied in the design and location of stereo speakers. Specially designed rooms are often used for stereo demonstrations.
- g) The reflection of sound by a parabolic dish is applied in the design of the microphone that is used to pick up bird songs. The same kind of microphone is used by TV crews at sporting events to pick up the chatter on the players' bench and the playing field.
- h) A knowledge of resonance is applied in the design of musical instruments and in the orchestration of instruments.
- i) Sound levels are reduced in the home through the use of sound-absorbing materials in construction and for furnishings.
- j) Recording studios can use electronic means to change the shape of a wave form and thus its sound.
- k) Electronic synthesizers are the result of a careful study of the wave forms produced by various instruments and the electronic duplication of these wave forms.

5. Societal Implications

- a) Music, in a variety of forms, is a part of daily life for most people.
- b) Some people risk ear damage from loud music yet will not tolerate sound of lower intensity in their workplace.
- c) Because people are very conscious of noise pollution, the locations of traffic arteries and supersonic-aircraft flight corridors are issues that should be dealt with by a variety of interest groups and the government.
- d) A great deal of money is spent by individuals and corporations to minimize noise levels at home, on the job, and in our environment.

6. Evaluation of Student Achievement

At least 50 per cent of the term mark for this unit is to be based on students':

- a) explanations for observations in laboratory activities;
- b) diagrams of wave types, the ear, variations in sound characteristics, interference, and resonance.

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*See the subsection entitled "Student Activities" on page 5.

7. Safety Considerations

a) Electronic devices and power supplies should have appropriate safety approval.
b) If electrical circuits are to be connected by students, the power supply should not be turned on until the teacher has checked the circuitry for continuity and polarity.
c) Care must be taken with respect to the magnitude of sounds produced and the proximity of the ear to these sounds.
d) See also core unit 4, "Electrical Energy".
e) For further information on safety, teachers should refer to Part 1, section 9, of this guideline.

8. Possible Extensions

Some students might:

a) use a sound-level meter to determine the sound intensity at various locations and distances relative to a source. The results can be displayed by means of graphs or charts;
b) tune an instrument, such as a guitar or a clarinet, by using beat frequency;
c) discuss how reflected sound waves (sonar) can be used to calculate water depth;
d) report on topics such as the following: (i) the design and operation of speakers in audio systems; (ii) the design of an electronic synthesizer; (iii) the human voice.

Core Unit 2

Light and Colour

Time: 18 hours

A great variety of sensory input enters the eyes, and sight is certainly a very highly valued sense. Light (sometimes in laser form) plays an increasingly prominent part in the lives of North Americans. Fibre-optics telephone communication, universal product codes that mark price and other information on goods for sale, laser surgery, and the use of optical fibres to examine the body are but a few examples. Our environment is enhanced by colour, a characteristic that is important in many aspects of our lives. In this unit students will investigate the reflection and transmission of light and colour and gain a better understanding of how light is used in the world about them.

This unit may be divided into topics such as the following:

- Reflection
- Plane and curved mirrors
- Refraction and internal reflection
- Convex and concave lenses
- Colour
- The eye

There are a number of interesting demonstrations that can be used to arouse students' interest. For example, they can be provided with an opportunity to view a good-quality hologram and be informed of how holograms are used on charge cards to make them more difficult to counterfeit (a simple application).

Discussion can be generated by shining a laser around the room and asking students whether the laser beam will be visible if the room is darkened. If the room is darkened, students will see that the laser beam is invisible unless some dust or mist is introduced into its path. A discussion of science fiction movies in which laser guns are used can then take place.

Other starting points for a discussion of useful applications of light today might include the following:

- a demonstration of a compact disc player and the advantages that it has over regular record players
- the transmission of a voice over a laser beam or other light beam
- a demonstration of a fibre-optics lamp

1. Objectives

Attitudes. Students will be encouraged to develop:

a) an appreciation of the importance of sight in their lives and of the need to care for the eyes properly (4h);
b) an appreciation of the psychological effects of colour;
c) an appreciation of the relationship between basic physical principles and applications of these principles (4a, 4c, 4e-4g, 4i).

Skills. Students will have the opportunity to develop skill in:

a) using diffraction gratings to determine the colours transmitted by a coloured filter placed over a white incandescent light source (2k-2m);
b) observing images in plane and spherical mirrors and convex and concave lenses (2b);
c) locating images produced by plane and concave mirrors and convex lenses (2b);
d) making generalizations about the location and characteristics of images produced by plane and spherical mirrors (2b, 2c);
e) drawing ray diagrams to illustrate the effect that plane surfaces, rough surfaces, and curved surfaces have on parallel rays of light (2c);
f) observing the effects that different transparent materials have on light passing through them and then drawing diagrams to show the path of light (2h, 2i);
g) constructing ray diagrams to scale to locate images produced by concave mirrors and convex lenses, given the focal length and location of the object (2j);
h) determining the focal length of a concave mirror or a convex lens (2d);
i) manipulating the equipment on an optical bench to determine the image characteristics for various object positions for both a concave mirror and a convex lens (2c, 2e);
j) interpreting observations of the refraction of light through plastic or glass to develop the general rules governing refraction (2k);
k) measuring angles of incidence, reflection, and refraction in the investigations involving ray boxes and reflecting or refracting surfaces (2a);
l) diagnose a person's eye ailment as being near-sightedness, far-sightedness, or astigmatism by looking through their glasses when they are held at arm's length.

Knowledge. Students will be expected to:

a) explain why glossy surfaces produce glare and rough surfaces do not;
b) label a diagram showing reflection from a plane mirror to indicate the following: incident ray, reflected ray, angle of incidence, angle of reflection (2a);
c) state the laws of reflection;
d) list the characteristics of the image produced by a plane mirror (2a);
e) locate the following on a diagram of a spherical mirror: vertex, centre of curvature, principal axis, principal focus, focal length;
f) describe the changes in direction that light will undergo as it enters a transparent material of different optical density at an oblique angle (2h);
g) describe the effect that (i) a convex and (ii) a concave transparent shape have on parallel incident rays of light (2i);
h) recognize the parts of the eye that play a direct role in forming an image on the retina and describe the function of each of these parts;
i) describe what is meant by (i) near-sightedness, (ii) far-sightedness, and (iii) astigmatism; identify possible causes of each; and indicate the lenses needed to correct each;
j) describe a procedure that will demonstrate that white light is composed of the spectral colours (2m);
k) explain why objects appear as a certain colour when illuminated by light of different colours (2l);
l) explain the operation of a coloured filter;
m) explain how an optical fibre transmits light around corners;
n) explain how properly oriented Polaroid sheets can absorb almost all of the light incident on them (2n).

2. Some Teaching Suggestions

a) There are many opportunities for student activities in this unit. Generally speaking, ray boxes that emit one or more rays of light can be used to study the behaviour of light in two dimensions (a plane). Optical benches can be used to study light in three dimensions.
b) An aquarium partially filled with water can be used to illustrate the reflection and refraction of light. If a few drops of milk are added to the water, a beam such as that produced by a laser will be clearly visible. If smoke is introduced in the space above the water, the beam will be clearly visible as it passes through air.
c) If a plane piece of glass is used as a mirror and a lit candle is used as an object, then another candle of the same height but not lit can be placed on the other side of the glass to locate the image position. This illustrates parallax in a very effective way and clearly shows that the image is located behind the mirror and not on its surface.

d) Students can stand in front of a large concave mirror and extend an arm towards it. They will see an image of their hand and arm coming towards them in the space between them and the mirror.

e) A pinhole camera can be used to introduce and illustrate the terminology used to describe images.

f) By taking a person's glasses, holding them at arm's length, and looking at a distant object, an individual can identify common eye ailments such as near-sightedness (objects appear smaller), far-sightedness (objects appear larger or inverted and smaller), and astigmatism (objects appear distorted in shape).

g) All students can be tested for colour-blindness, by means of the special charts or booklets that are commonly available for testing. It is not uncommon for students to be unaware of the fact that they are colour-blind.

h) Some careers (e.g., interior designer, helicopter pilot) require proper colour vision.

i) Replica-diffraction gratings are very effective in dispersing light. These can be used to illustrate the concepts in the section on colour.

j) People in careers that involve an understanding of some aspect of light (e.g., photographers, optometrist assistants, interior decorators, lens grinders, camera salespeople, health and safety inspectors, forensic-science technicians) could be invited to visit the class to describe their work.

k) One or more students could be asked to find out what the illumination requirements are for various public areas and then measure the light intensity at various locations in the school.

l) Simple Polaroid filters can be used to illustrate that the light reflecting from non-metallic surfaces is partially polarized, as is the light from the sky.

m) A store manager could be invited to describe all the information that the universal product code carries and how this information is utilized in his/her business.

n) A beautician trained in the analysis of colours could be invited to determine whether a specific person is a "summer", "winter", "fall", or "spring" person and to show how this determines the colour of clothing that the person should wear.

o) Eyes obtained from an abattoir can be dissected so that students can see their parts. If an eye has been taken from a recently slaughtered animal, the lens will be clear enough to enable students to determine its focal length.

3. Student Activities

Students are to:

*a) compare the angle of incidence and the angle of reflection when light is reflected from a plane mirror;

*b) locate the image produced in a plane mirror and determine its characteristics;

*c) determine the effect that concave and convex reflecting surfaces have on parallel rays of light;

*d) determine the focal length of a concave mirror and locate the image produced by this mirror for various object positions;

e) determine the characteristics of the image produced by a convex mirror when an object is placed in front of the mirror;

*f) determine the paths taken by a number of different rays of light that strike a rectangular prism;

g) determine the paths taken by a number of different rays of light that strike the centre of the flat side of a semicircular prism;

h) investigate the effect of increasing the angle of incidence as light passes from a transparent material into air, observe total internal reflection, and determine the conditions needed to produce it;

*i) investigate the effect that convex and concave transparent shapes have on parallel rays of light;

*j) determine the focal length of a convex lens and determine the characteristics of the image produced for a number of different object distances from the lens;

*k) disperse white light, using a triangular prism or a diffraction grating;

*l) record the appearance of coloured objects when placed separately under red, blue, yellow, and green light;

m) record the colour produced when white light is shone through individual filters and combinations of different filters;

n) investigate different sources of polarized light, using Polaroid sheets.

4. Applications

a) Lens systems are used in many common optical instruments, including cameras, projectors, microscopes, and telescopes.

b) There are a number of similarities in the functioning of the camera and the eye.

c) Optical fibres are used in an ever-increasing number of applications, such as medical diagnosis and information transmission.

d) Total internal reflection is employed in prism-type binoculars, periscopes, and single-lens reflex cameras.

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*See the subsection entitled "Student Activities" on page 5.

e) Curved mirrors are used as cosmetic mirrors, rear-view mirrors on vehicles, and surveillance mirrors in stores.
f) The colour of sets and costumes in theatrical productions can be controlled by illumination involving combinations of coloured lights.
g) Colour co-ordination and impact influence the design of fashions and cosmetics for both men and women.
h) Polaroid sunglasses can eliminate glare because light reflected from non-metallic surfaces is partially polarized.
i) The use of the universal product code and lasers at checkout counters enables businesses to collect considerable information as the products pass through the checkout.

5. Societal Implications

a) The development of optical instruments has permitted the study of microbiology, which has brought many benefits in health care.
b) The telescope provided data about the moon, which in turn provided significant information to those involved in space programs.
c) Technological applications of principles of light and colour have provided many devices, such as lasers, that have improved scientific research techniques as well as the quality and enjoyment of life.

6. Evaluation of Student Achievement

At least 50 per cent of the term mark for this unit is to be based on students':

a) laboratory work and reports of activities;
b) practical laboratory tests, such as accurately determining the focal length of a concave mirror or convex lens;
c) diagrams, including ray diagrams, illustrating the behaviour of light.

7. Safety Considerations

a) Appropriate procedures should be developed and followed if candles are used as light sources. Ray boxes or similar devices can be used to determine the path of light through transparent objects. Lamps or other sources can be used with lenses to form images. All of the electrical equipment used should have appropriate safety approval.
b) If lasers are used in this unit, students must be instructed not to look directly down the beam.
c) For further information on safety, teachers should refer to Part 1, section 9, of this guideline.

8. Possible Extensions

Some students might:

a) investigate the lens system used in an optical instrument (e.g., a telescope, a pair of binoculars) and explain how it works;
b) study colour vision and colour-blindness. Students can check to see if they are colour-blind. An optometrist or eye doctor might speak on these topics;
c) investigate the importance and psychology of colour in advertising and marketing;
d) observe the production of prints from colour photographic film;
e) explore the variety of careers in the diverse fields that are involved with all aspects of light and colour.

Core Unit 3

Heat

Time: 18 hours

When we use energy, we almost always transform it into heat, which is then released into the environment. As a result this energy is not completely available to us for future use. This has raised concerns about future energy supplies. Heat energy itself has a wide range of applications in our modern society. It is the form of energy that powers our transportation systems. It is involved in the processing and manufacturing of many materials used in industry and in consumer goods. Heat transfer from a variety of sources and an understanding of home heating systems and related concepts are emphasized in this unit.

This unit may be divided into topics such as the following:

- Heat and temperature
- Kinetic molecular theory
- Heat and its transfer: applications in the home
- Heating and cooling curves
- Heat exchange in mixtures
- Latent heat
- Heat pumps

A "drinking bird", available from science novelty stores, could be set up. (A model in which the fluid and its movement inside is visible would be preferred.) Students could be asked to hypothesize about why the bird is acting as it does. Final explanations should not be provided at this point, but the bird could be brought back out as progress is made through the unit, so that by the end of the unit students understand its operation.

An alternative activity would be to pour a number of cups of coffee, some in styrofoam cups, some in paper cups, some in large cups, some in small cups, some with lids, and some without lids. Students should be asked in what order the cups will reach a specific temperature, such as 60°C. A complete explanation will gradually evolve as the unit is discussed and topics such as heat transfer and quantity of heat are developed.

1. Objectives

Attitudes. Students will be encouraged to develop:

a) an appreciation for the importance of heat energy in technology and in nature (3c, 3h);
b) an awareness of the possible effects of advancements in technology (3h);
c) a commitment to conservation practices.

Skills. Students will have the opportunity to develop skill in:

a) measuring the temperature, mass, and volume of different materials (3d-3g);
b) recording and organizing data from experiments and activities (3);
c) using the equation $Q = mc\,\Delta t$ to solve problems involving heat transfer;
d) plotting and interpreting heating and cooling curves (3d).

Knowledge. Students will be expected to:

a) state the major points of the kinetic molecular theory (2b);
b) explain the difference between temperature and quantity of heat in terms of the kinetic molecular theory;
c) explain the transfer of heat by conduction, convection, and radiation in home-heating systems or in other applications (2c, 3h, 4b);
d) describe the effect that the colour and texture of an object have on the radiation and absorption of heat (3b);
e) interpret a cooling or heating curve for a substance (2d);
f) state the principle of heat exchange in mixtures;
g) use the equation $Q = mc\,\Delta t$ and state the factors that determine the amount of heat energy gained or lost by a substance;
h) select the materials best suited for heat storage from tables of specific heat capacity;
i) describe the operation of a heat pump or refrigerator (3h).

2. Some Teaching Suggestions

a) If the quantity of equipment is limited, students may rotate through different laboratory stations to investigate heat-transfer experiments.

b) A model of the kinetic molecular theory can be developed by means of one or more of the following: (i) demonstration models such as overhead-projector kinetic-molecular demonstrators or electrostatic-generator demonstrators, or other similar models; (ii) Brownian motion demonstrations; (iii) the diffusion of a perfume or other scent through a room; (iv) the diffusion of a coloured solute through a colourless solvent.

c) Heat flow from higher to lower temperatures can be illustrated by having students place their hands in separate baths of water, one very cold and the other warm. After several minutes students should place both hands simultaneously into a lukewarm bath of water.

d) - The relationship between heat gained and mass can be determined from heat curves obtained when different masses of a liquid are heated and the temperature is taken at one-minute intervals. The data for each liquid can be used to plot a heating curve on a temperature-versus-time graph.
   - The fact that different substances have different heat capacities can be determined from heat curves obtained when identical masses of different liquids are allowed to cool. The liquids should be warmed by immersion in a hot-water bath. The temperature of each liquid should be taken at one-minute intervals. Students should use data to draw a separate heat curve for each liquid on the same graph.

e) Other heat curves can be obtained by placing hot water in a calorimeter or other container and measuring the rate of cooling. The cup in the calorimeter (or container) can be surrounded (packed) by a substance such as paper or styrofoam. The insulating property of each packing material can be inferred from the heating curve of the water in each case. Teachers may wish to make this into a contest. Students could be challenged to see who can design a container of given dimensions that will keep a cup of hot water warm for the longest period of time.

f) Identical quantities of water can be placed in containers of different colours (for example, silver versus black). The rate at which the water warms up when the containers are exposed to a heat source such as an incandescent lamp under identical conditions can be used to plot heat curves. Conversely, identical amounts of water in different-coloured containers can be allowed to cool to obtain cooling curves.

g) The heat of the fusion of ice can be determined by placing cubes of ice in a known mass of warm water inside a calorimeter or styrofoam cup. The temperature of the water should be measured before the ice is added. The mixture should be stirred until the temperature reaches 0°C, with the temperature recorded at one-minute intervals. The excess ice should then be removed and the mass measured. The final mass of water in the container should be measured, and the mass of the melted ice should be calculated. By equating the heat lost by the warm water to the heat gained by the ice, students can determine the heat of the fusion of ice.

   One method for determining the heat of the vaporization of water that simplifies the mathematics involves the use of an electric kettle for which the power rating is known. Water is added to the kettle, and the mass is determined. The kettle is then plugged into an outlet. Once the water begins to boil, the timer is started. The water is allowed to boil for a specific period of time before the kettle is disconnected and its mass found again. The mass of water converted to water vapour and the energy used are then easily calculated.

h) Students should be provided with opportunities, if possible, to inspect dismantled small engines, models of heat engines, or air conditioners.

i) Students could be asked to contact and then visit local businesses to obtain literature and information on the insulating characteristics of materials, as well as on the costs and characteristics of different home-heating systems. The most cost-effective insulation for a home could be determined. The most economical heating system for a home could also be established.

3. Student Activities

Students are to:

a) investigate heat transfer by conduction, convection, and radiation;

b) determine experimentally the effect of colour on the radiation and absorption of heat;

c) investigate samples of popular commercial insulation and building products and related literature and compare the R values and costs;

*d) perform experiments to investigate the rate at which different liquids warm up or cool down and plot heating or cooling curves from the data obtained;

*e) determine experimentally the amount of heat energy exchanged when hot and cold water are mixed;

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*See the subsection entitled "Student Activities" on page 5.

*f) determine experimentally the specific heat capacity of a metal;

*g) determine the latent heat of the fusion of ice or the latent heat of the vaporization of water;

*h) prepare an essay, a report, or a video on a heat-related topic such as passive solar heat, thermal pollution, the greenhouse effect, ground-water heat pumps, high-efficiency furnaces, biomass as an energy source, hypothermia, heat engines, energy conservation in the home, and heat energy and living organisms.

4. Applications

a) Heat energy is one of the major energy sources in our society. Heat may also be used to produce electricity.

b) The principles of heat transfer are used to design thermopane windows, storm doors, and insulating materials in general.

c) The terminology related to heat engines and their principles of operation is used in automobile advertising (e.g., 2-L engine, fuel injection, turbocharging).

d) The search for alternative energy sources and ways of conserving energy are based on an understanding of heat.

e) Spacecraft, such as the space shuttle, use ceramic shielding heat ablation for heat dissipation.

5. Societal Implications

a) The heat pollution of rivers and lakes is a cause for concern in some parts of the globe.

b) The use of heat energy in a variety of ways has improved our standard of living.

c) Innovative heating and cooling systems may be necessary in homes and buildings in the future.

d) The conservation of energy and the development of alternative energy sources will become more important as supplies of conventional fossil fuels dwindle.

e) Pollutants from some heat engines may pose serious health hazards and create environmental problems.

6. Evaluation of Student Achievement

At least 50 per cent of the term mark for this unit is to be based on students':

a) laboratory reports and practical work (a minimum of 20 per cent);

b) essays or reports on heat-related topics;

c) problem assignments.

7. Safety Considerations

a) Open flames should be used only in a laboratory with flat desks or tables, adequate ventilation, a fire extinguisher, and a fire blanket.

b) Students should wear protective eyewear when using flames or heating liquids. Loose hair and clothing should be tied back.

c) Liquids other than water should be heated in a water bath or on a hot plate rather than over an open flame. Some liquids or their vapours can ignite easily.

d) When liquids other than water are heated, there should be adequate ventilation to remove the vapours.

e) When alcohol or other flammable gases are present in the laboratory, there should be no open flames.

f) Volatile liquids like alcohol should be stored in approved containers. The containers should not be removed from the storage area.

g) Students must take special precautions to avoid burns when handling hot containers and liquids.

h) For further information on safety, teachers should refer to Part 1, section 9, of this guideline.

8. Possible Extensions

Some students might:

a) evaluate the merits of different house plans and materials for their effectiveness in minimizing heat gain or loss;

b) study proposed designs of heat engines;

c) study the properties of ceramics used as heat shields or study ablative cooling techniques;

d) investigate the use of remote sensing for pollution monitoring, crop management, cancer detection, and resource exploration;

e) develop a model that explains the earth-sun system in terms of a heat engine;

f) study possible causes for the ice ages;

g) investigate the processes of extracting and refining petroleum.

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*See the subsection entitled "Student Activities" on page 5.

Core Unit 4

Electrical Energy

Time: 18 hours

Every day electrical energy is used to power devices that are a part of our current lifestyle. Life would be considerably different without electric lights, washers, dryers, refrigerators, computers, and telephones. Many industrial processes exist because electric motors have been developed to perform specific tasks through the use of electrical energy. In this unit students will study some of the fundamental concepts underlying electricity and magnetism and see how these concepts have been put to use by technology.

This unit may be divided into topics such as the following:

- Current, voltage, and resistance
- Electric circuits: series and parallel
- Energy, power, and costs
- DC motors
- Electrical generators
- Transformers
- The transmission of electrical energy

As an introductory demonstration, students could be shown a number of ways in which current electricity can be produced and asked to identify the energy conversion that is occurring. The following are some possibilities:

- *chemical to electrical*. A zinc plate and a copper plate inserted into an apple, an orange, or some other fruit will readily produce a deflection on a galvanometer.
- *heat to electrical*. A simple thermocouple can be heated at the junction of two metals to produce electricity.
- *light to electrical*. A photocell exposed to light produces an electrical current.
- *mechanical to electrical*. A magnet inserted into a coil produces a current.

In each case students could be asked not only to identify the energy conversion but also to give an example of how each conversion is used in a device that is available commercially.

As a follow-up activity, each student could be given access to flashlight batteries, miniature light bulbs, and wires and asked to make the light bulb light up, using as few components as possible. After successfully completing the task, they should draw a schematic diagram of the circuit that they have connected.

1. Objectives

Attitudes. Students will be encouraged to develop:

a) a curiosity about how electrical devices work (3a-3d, 4a, 4d);
b) an appreciation of the large amount of electrical energy that is required to satisfy society's demands (3c, 4c-4e);
c) a concern for the wise use of electrical energy (4e);
d) an appreciation for how scientists develop explanations for observed phenomena;
e) a respect for the potential hazards involved in working with electricity;
f) an interest in the variety of employment opportunities related to electrical energy (3a-3d, 4c, 4d).

Skills. Students will have the opportunity to develop skill in:

a) following circuit diagrams to construct electrical circuits;
b) drawing circuit diagrams as part of the design to solve the question raised in an investigation;
c) connecting ammeters, voltmeters, and ohmmeters correctly in a circuit;
d) selecting appropriate range settings on ammeters, voltmeters, and ohmmeters;
e) recording ammeter, voltmeter, and ohmmeter readings in a chart or table;
f) using the relationships that govern current, potential difference, and resistance in series and parallel circuits to solve simple circuit problems;
g) reading an electric meter, such as the one found in all homes, that records electrical energy use;
h) using the equations to make simple calculations about an electrical circuit;
i) inferring the causes of such things as the blowing of a fuse by a toaster and a kettle that are plugged into the same circuit.

Knowledge. Students will be expected to:

a) identify the quantities and the units for each term in the Ohm's law formula;
b) explain why electrical outlets in homes, schools, and businesses are wired in parallel and not in series;

c) recognize that it is standard practice to supply homes with both 120 V and 240 V AC electrical power;
d) explain how a fuse or circuit breaker protects a circuit;
e) explain, given a diagram of a DC motor, why the armature rotates;
f) determine the direction of current flow, given a diagram of an electrical generator and the direction in which the armature is being rotated;
g) explain the difference between direct and alternating current;
h) describe the differences in construction and function between step-up and step-down transformers;
i) state the relationship among output and input currents, voltages, and power in a transformer when the number of turns in the primary and secondary coils is known.

2. Some Teaching Suggestions

a) Teachers should be aware that some of the fundamental concepts in this unit were taught in core unit 4 of the Grade 10 course. Some review will of course be required, but the background that students have should be taken into consideration.
b) Since a number of the investigations in the Grade 10 unit used miniature light bulbs as loads, it is advisable to use resistors in this unit.
c) Having the class construct a flashlight battery or dry cell from a kit could be a meaningful activity, since students use a lot of batteries in their portable radios, tape recorders, and cassette players.
d) Care must be taken to select resistors that match the power supplies to be used. For safety reasons potential differences above 30 V should be avoided.
e) Through the selection of just the right gauge and length of nichrome wire to match the power source to be used, it is possible to construct a homemade resistor that will become red-hot when connected to the power source at its highest potential difference. This makes an excellent introduction to the concept of resistance, because while the nichrome-wire resistor will be red-hot, the connecting wires (good conductors) will remain cool.
f) If students establish early in the unit that ammeters are connected in series and voltmeters in parallel, teachers can ask them to design the circuit diagrams for the investigations that they will conduct.
g) Slides taken by the teacher of the meters used in the course are an excellent way to teach the meter-reading skills students will require to complete successfully the readings in the investigations.
h) Students should be urged to bring their portable electrical devices (e.g., tape recorders, radios) to class so that the following can be determined: size of battery, potential difference of one battery, way in which batteries are positioned in the device, total potential difference produced by this arrangement of batteries.
i) Teachers could provide students with commercial batteries of different sizes (e.g., AA, A, C, D) and have them discover that all of these batteries produce the same potential difference.
j) A simple probe made from a neon light will distinguish between AC and DC.
k) An ohmmeter can be used to measure the resistance of the body. The effect on body resistance of wet and dry skin readily becomes apparent.
l) To get a feeling for the significance of the concept of resistance, students could use an ohmmeter to measure the resistance of different appliances, such as kettles, irons, electric heaters, and assorted resistors. If light bulbs are used, teachers should be aware that the resistance of a bulb changes when it gets white-hot.
m) Teachers could provide students with a challenge by constructing mystery boxes. Each box could have six terminals extending into the box. Inside the box resistors or wires could be connected in series or simply by themselves. Students would have to determine the contents of the box and provide the teacher with a circuit diagram showing the arrangement and size of the resistors and conductors.
n) To appreciate the amount of energy that a light bulb or another device actually uses, students can construct a human-powered generator, using an old bicycle and an alternator from a car. The rear tire can be removed from the bicycle and used as a pulley for a belt that is connected to the alternator. Various contests could be conducted, for example, to determine who can produce the greatest power output or who can heat a cup of water to boiling the fastest.
o) If students bring an adapter for a portable radio, tape recorder, computer, or another device to class, they can measure the potential difference of its output. All of these devices contain step-down transformers.
p) Activities on electromagnetic induction should be designed so that students can manipulate the variables, such as the number of coils, the strength of the current, and the type of core in the coils. Students should make generalizations about the effects of the variables rather than establish mathematical relationships.
q) This unit is especially suitable for a careers emphasis. There are a number of careers involving a knowledge of electricity that students in general-level courses can aspire to (e.g., electrician, electronics technician, Ontario Hydro lineperson, appliance repairperson, appliance salesperson, lab technician).

3. Student Activities

Students are to:

a) construct a flashlight battery or a dry cell from a kit;
*b) construct flashlight batteries or dry cells in series and determine the potential difference produced by a single cell as well as by the series combination;
*c) connect flashlight batteries or dry cells in parallel and determine the potential difference produced by single cells as well as by the parallel combination;
*d) construct a simple circuit and use it to verify Ohm's law;
*e) construct simple series and parallel circuits and determine the relationships governing current, potential difference, and resistance for each of these circuits;
*f) read an electric meter daily for several days to determine the electrical energy used and calculate the cost, using local electrical rates;
g) record the information found on the electrical plates of several electrical appliances in the home or school and determine the cost of operating them for normal operating periods;
h) build a working DC electric motor, using simple materials or a kit;
*i) experimentally determine how a current can be induced in a coiled conductor;
j) investigate the factors that affect the strength of an induced current;
k) observe the potential differences in the secondary and primary coils of a step-up and step-down transformer.

4. Applications

a) Loudspeakers, electromagnetic relays or solenoids in cars, washing machines, dishwashers, doorbells, and magnetically propelled monorail trains use changing magnetic fields for lifting and propelling.
b) Simple electrical motors in such items as sewing machines, food processors, hair dryers, car windows, garage-door openers, fans, refrigerators, clothes dryers, and electric razors are applications of electromagnetism.
c) Relative motion between conductors and magnetic fields is used to generate electricity in applications on as large a scale as the production of electrical energy by Ontario Hydro and on as small a scale as bicycle light generators. Changing magnetic fields are used in transformers that distribute electricity across Ontario, operate electric doorbells, and charge the rechargeable batteries in items such as hand-held calculators.
d) The same electric and magnetic fields that make motors and generators work are also directly involved in the solid-state microcircuits used in communication systems and computers.

5. Societal Implications

a) The quality of life for many is enhanced by the variety of devices that have been developed to convert electrical energy into useful work, light, and sound.
b) The development of electrical lighting has permitted work to be carried out around the clock.
c) A large part of the Canadian economy is dependent on the electrical industry. The manufacture and distribution of electrical goods is a major source of employment and contributes to the national wealth.
d) The ease with which electrical energy can be converted to other forms of energy has led to an increase in the number and types of electrical devices in our society. The design, development, manufacture, and distribution of these goods now and in the future will provide many career opportunities in such fields as electrical engineering, electrical technology, merchandising, and industrial design.
e) A number of issues involved with the conservation, production, and distribution of electrical energy are subject to public debate.
f) Wide distribution of electrical energy has brought modern conveniences to most of the population of Ontario.
g) Since certain appliances use a large amount of electrical energy, their energy costs should be considered before they are purchased or used excessively.
h) The demand for more and more cheap electrical energy has resulted in an increase in the use of nuclear power.
i) There is much public debate about the use of nuclear energy to produce electrical energy.

6. Evaluation of Student Achievement

At least 50 per cent of the term mark for this unit is to be based on students':

a) laboratory work, projects, and reports;
b) ability to connect meters in circuits properly and read them correctly;
c) construction or assembly of electrical circuits and devices.

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*See the subsection entitled "Student Activities" on page 5.

7. Safety Considerations

a) Power supplies, meters, and circuit components should have appropriate safety approval.
b) Students should be cautioned that the range of any meter used must be appropriate for the current or voltage being measured.
c) Power should not be turned on in any circuit until the teacher has checked the circuitry for continuity, polarity, and correct meter ranges.
d) Students should be well informed of the hazards associated with electric circuits and be told not to touch circuit connections once the power supply has been turned on.
e) Students should be warned that dry cells may explode if shorted out.
f) For further information on safety, teachers should refer to Part 1, section 9, of this guideline.

8. Possible Extensions

Some students might:

a) discuss magnetic levitation as a means of propulsion in transportation systems;
b) investigate and demonstrate how the motor principle is used to measure current and voltage in ammeters and voltmeters;
c) construct a current balance to show the factors that affect the force between current-carrying conductors;
d) study the construction, action, and applications of relays;
e) study the use of electricity and magnetism in a personal cassette recorder.

Core Unit 5

Motion

Time: 18 hours

Motion is so natural to us that we are often unaware of it and fail to realize its significance. The analysis of motion often helps us make inferences about the energy possessed by an object and the forces acting on it. In order to provide students with an understanding of some of the concepts associated with motion, this unit will involve students in the examination of several kinds of motion, some of the factors that govern motion, and a number of conclusions about motion.

This unit may be divided into topics such as the following:

- Speed
- Speed-time graphs
- Acceleration (scalar)
- Force and motion
- Work, energy, and power
- Kinetic and potential energy
- Energy transformations

The unit can be introduced by means of a radio-controlled car. Perhaps a student could bring in such a car and demonstrate it to the class. The car could then be used to illustrate various kinds of motion and terms such as *acceleration*, *deceleration*, *speed*, and *distance*. It could then be pointed out that one of the major objectives of the unit is to develop the vocabulary needed to describe and understand motion and to measure some aspects of motion.

1. Objectives

Attitudes. Students will be encouraged to develop:

a) a curiosity in seeking explanations for phenomena involving motion (2g-2i, 3a-3c, 4a);
b) an appreciation for the need to use good judgement when operating a vehicle or riding a bicycle or motorcycle (2h, 2m).

Skills. Students will have the opportunity to develop skill in:

a) measuring distances and times;
b) calculating speed, average speed, acceleration,* work, power, kinetic energy, and potential energy (2a-2d, 2f, 2g, 2i, 3a);
c) recording experimental data (3a, 3b);
d) plotting speed-time graphs and determining their slopes (3b);
e) making and testing hypotheses and designing experimental procedures (3d).

Knowledge. Students will be expected to:

a) define the following: average speed, uniform speed, acceleration, inertia, work, power, kinetic energy, potential energy;
b) determine the average speed of an object, given the distance it travels in a specific time;
c) determine the acceleration of an object from its speed-time graph or from the change in speed that it undergoes in a specific time interval;
d) describe the motion of an object, given its speed-time graph;
e) explain everyday events in terms of Newton's laws of motion (e.g., why one should wear a seatbelt) (2j);
f) solve simple problems using $F = ma$;
g) explain how the mass of an object and the nature of the surfaces it contacts affect the size of static and kinetic friction (2j, 2k);
h) draw free-body diagrams to illustrate the forces acting on an object when it is (i) at rest, (ii) moving with uniform speed in a straight line, and (iii) accelerating or decelerating uniformly (2l);
i) explain why an object falling through air reaches a terminal speed (2l);
j) recall the definition of *work* and use the formula $W = Fd$ to solve simple problems (2a);
k) determine the power, given the work done and the time taken (2k);
l) describe the changes in potential and kinetic energy for a body in free fall or a body sliding on a frictionless slope (3c, 3d);
m) state the law of conservation of energy;
n) determine the kinetic energy of an object, given its mass and velocity, and the potential energy of an object, given its mass and height.

2. Teaching Suggestions

a) The key to a successful unit on motion in a general-level course lies in avoiding excessive mathematical rigour and in using situations that students find relevant and interesting.
b) To introduce the concept of speed, teachers could take their students outdoors, mark off 100-m stretches along the side of a road, and determine the time taken for cars to travel this distance. The local police department may co-operate and determine the speed of the cars by means of radar.
c) If calibrated recording timers are available, they could be used to determine how long it takes an object to move a certain distance. For example, how long does it take for a mass to fall 1.0 m?
d) Students could be invited to bring battery-operated toys to class and to make ticker-tape records of their motion. If the tapes are then cut up into pieces of equal time and pasted side by side they become a speed-time graph.
e) For a study of acceleration students might make a ticker tape of their own motion for a period of one or two seconds.
f) Computer hardware and software are available to make it possible to use the computer as a millisecond timer.
g) This unit could be built around the hobby of rocketry if board policy permits. The construction of model rockets and the recording of flight information provide ample opportunities to measure speeds, distances, acceleration, times, and heights.
h) Information in driver-training manuals fits nicely into this unit and could be used as a resource.
i) There are many non-mathematical examples of Newton's laws of motion that can be taken from students' personal experiences.
j) For the investigation involving Newton's second law, care should be taken to keep the method simple. The following are some possibilities:

  - One student on foot can pull another on roller skates while applying a constant force. The time taken to go a specific distance (e.g., 5 m) can be determined.
  - Students can accelerate a dynamics cart to which is attached a ticker tape by using an elastic band stretched a specific amount. While it is difficult to get good quantitative data in this way, the activity will provide students with a good intuitive feel for the second law, and the results should show that increased force results in increased acceleration.

k) Students can determine their power rating. Instead of running up a flight of stairs, they can drag a trunk across the room. Again, a method will have to be devised to determine the force required to slide the trunk. (A bathroom scale calibrated in newtons could be used in a modified way to do this.)

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*The acceleration problems presented in this unit should deal only with situations in which students are given the change in speed and the elapsed time. Problems are to be limited to uniform acceleration.

l) An effort should be made to show the relevance of the study of motion to everyday life. Students could be asked to prepare a short demonstration of an example of this for presentation to the rest of the class. For example, they might demonstrate (i) reaction time and distance travelled when driving a car, (ii) the physics of sports, or (iii) safe driving practices.

m) This unit provides an opportunity to invite a police officer into the classroom and to relate the physics of motion to safe driving habits.

3. Student Activities

Students are to:

*a) measure and tabulate distances and time intervals for a person or an object considered to be moving uniformly and calculate the average speed for the motion;

*b) record the data necessary to plot a speed-time graph for a moving object, such as a person or a toy, and describe the motion depicted by the resulting graph;

*c) determine the coefficient of friction for different surfaces in contact and determine the effect that the mass has on the force of friction and on the coefficient of friction;

*d) develop hypotheses regarding factors that will influence the rate of fall of objects in air, such as feathers, sheets of paper, or cards; design and carry out experiments to test these hypotheses; and report on the experiments by comparing their results with the hypotheses;

*e) determine the acceleration experienced by a freely falling body;

*f) determine the power developed by a student carrying out a task, such as dragging a mass through a specific distance;

g) determine the mass and speed of a moving object and calculate its kinetic energy.

4. Applications

a) A knowledge of stopping distances at different speeds and on different surfaces is important for drivers.

b) Free fall, air resistance, and terminal velocity are concepts that are important in sky diving, gliding, ballooning, and meteorology.

c) Friction is a necessary force in many situations involving motion.

d) The study of human kinetics has produced improved coaching techniques in sports. This has resulted in better performances by athletes.

e) Improvements in the efficiency of energy conversion often lead to technological changes.

5. Societal Implications

a) An understanding of the relationship among distance, speed, time, and energy influences safety laws and driving habits.

b) The capability of moving at ever-greater speeds in the air has effectively created a global village.

c) Some cars are equipped with powerful optional engines to enable them to accelerate faster. This involves greater fuel consumption and hence the faster depletion of non-renewable resources.

d) An understanding of force and motion has led to space exploration.

e) The ability to measure energy produced and consumed has led to increased efficiency in the use of energy in many processes.

6. Evaluation of Student Achievement

At least 50 per cent of the term mark for this unit is to be based on students':

a) experiments and lab reports;

b) graphing and graphical analysis.

7. Safety Considerations

a) If air tables or tape timers are used in any experiment, this equipment and its wiring must be in good condition and have an appropriate safety approval.

b) If bicycles are used in motion experiments, students must be provided with instructions regarding safety precautions and then follow them precisely.

c) For further information on safety, teachers should refer to Part 1, section 9, of this guideline.

8. Possible Extensions

Some students might:

a) determine the coefficient of friction for different types of surfaces;

b) discuss the friction effects involved with very high speeds in aircraft;

c) consider the relationship between the fuel requirements and the speed of a car (the merits of imposing a lower speed limit in Ontario could be discussed);

d) determine their power when performing some mechanical task.

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*See the subsection entitled "Student Activities" on page 5.

Optional Unit 1

Fluids

Time: 10 hours

One of the technologies that has had an impact on modern society is that of fluids. There are few vehicles or pieces of machinery designed to carry large loads that do not have a hydraulic or pneumatic system for either power or control. Aerodynamics, which is the science of the fluid air, has given us the knowledge to fly and to sail. Hydrodynamics, which is the science of water in motion, has given us the knowledge to move effectively through and over the water. In this unit students will study fluids at rest and fluids in motion to gain an insight into the applications of fluid technology.

This unit may be divided into topics such as the following:

- Air pressure
- Pressure in liquids, including Pascal's law
- Buoyancy and Archimedes' principle
- Surface tension
- Fluids in motion
- Bernoulli's principle

If the barrel of a Bunsen burner is removed and the burner is then connected to the exhaust of a vacuum pump, a table-tennis ball will levitate above the burner when the vacuum pump is turned on. The ball will even stay in the stream of air if the Bunsen burner is tilted a small amount to one side. This demonstration should generate considerable interest on the part of students and should provide a good introduction to fluids. A complete explanation of what is happening must be left until later in the unit.

1. Objectives

Attitudes. Students will be encouraged to develop:

a) an appreciation for the effects of fluids on our existence (3c, 3d, 4a, 4f);
b) a curiosity about how fluids are used to do work (3b, 3c, 3g, 3h, 4b);
c) an appreciation of the reason for streamlined shapes in animals, structures, and vehicles (3f, 4d).

Skills. Students will have the opportunity to develop skill in:

a) measuring mass, volume of a liquid, and the force of gravity on an object;
b) constructing a manometer;
c) inferring causes of phenomena such as the changes in the height of a column of fluid;
d) solving simple problems involving Archimedes' principle;
e) making and testing hypotheses and controlling variables for an investigation into which liquids will exhibit the greatest surface tension;
f) providing explanations after observing the effects of moving fluids on objects;
g) solving simple problems involving Pascal's law.

Knowledge. Students will be expected to:

a) define *pressure* (2a, 2b);
b) give some examples of phenomena that are caused by differences in air pressure and explain each (2a, 2b);
c) explain how a barometer measures air pressure (2b);
d) state the relationship between pressure in a fluid and depth (2b);
e) state Archimedes' principle and use it to explain related phenomena (2c);
f) explain and apply Pascal's law (2b);
g) explain what is meant by the term *surface tension* and give some examples of it (2d).

2. Teaching Suggestions

a) A manometer can be made of glass tubing or clear plastic tubing bent in the shape of a U and partially filled with coloured water. A pressure sensor for the manometer can be made by securing a thin rubber membrane over the plastic top of a thistle tube. The pressure sensor is connected to one of the arms of the manometer by means of a flexible tube. When the "pressure sensor" is held in a fluid, the liquid in the manometer will be displaced.

b) Different liquids, such as water, alcohol, oil, and concentrated salt water, can be used to show that pressure depends on the density of a fluid as well as on the depth of the fluid. A tall container such as a hydrometer jar will minimize the volume of liquid that has to be used. If the densities of the different liquids are determined, the relationship $P = gd$ can be developed.
c) Pascal's law can be demonstrated if a container large enough for the pressure sensor to be moved around in is available. A swimming pool is an ideal place to demonstrate Pascal's law, since students relate pressure on the ears with depth in a swimming pool.
d) A tall juice can punched with holes at several levels can be used to illustrate the variation of pressure with depth.
e) In activities 3a and 3b the kilopascal should be introduced as a unit of pressure, and students should be informed that 101 kPa is the atmospheric pressure at sea level. This pressure can be related to 760 mm of mercury and 10 m of water. A discussion of the variation of air pressure with altitude and the need for humans to have between 110 mm and 160 mm of oxygen pressure for survival can be an interesting extension of these two activities.
f) Air pressure can be effectively demonstrated by taking an empty metal can, placing a small amount of water inside, and heating it until it boils. The cap on the can is then replaced, and cold water run over it. The condensing water vapour inside the can will cause the pressure inside to drop drastically. The outside air pressure will then cause the can to buckle.
g) Students can be given pieces of aluminum foil of the same size and challenged to see who can build the boat that can hold the most washers without sinking.
h) Surface tension can be effectively demonstrated by carefully placing straight pins on the surface of the water in a beaker. The pins will remain at the surface because of the surface tension. However, if a drop of detergent is added to the water, the pins will sink because of the decrease in surface tension.
i) Simple demonstrations of Bernoulli's principle include blowing across the top of a sheet of paper or between two suspended table-tennis balls. The principle can be used to explain many everyday events, such as curving baseballs, the lift of airplane wings, and the action of carburetors. All of these can be explained without the use of mathematical details.
j) One motivational demonstration would be to prepare a bed of nails and ask a student to lie down on it. The bed of nails should be prepared by pounding nails about 1 cm apart through a piece of plywood that measures about 45 cm by 75 cm. The board must be carefully prepared so that all nails penetrate the board perpendicular to it and extend through it the same distance. Although considerable time and a large quantity of nails are required to prepare such a board, it will last indefinitely and will supply many classes with a memorable demonstration.

3. Student Activities

Students are to:

*a) investigate several activities that illustrate air pressure, for example, drawing liquid through a straw, supporting a volume of water in an inverted container by means of a piece of cardboard, trying to lift a flat piece of glass from a smooth table top, and using syringes (8e);
*b) construct a water manometer and use it to determine relative pressure at different levels in different fluids (6b, 8a-8d);
*c) investigate Archimedes' principle for objects that (i) sink in water and (ii) float in water;
*d) investigate qualitatively the difference in the surface tension of several different liquids (8f);
e) conduct a simple investigation of the effect of streamlining on the turbulence created by an object in a moving fluid (6c, 8g, 8h);
f) determine how a change in the cross-sectional area of a moving fluid changes the speed of the fluid;
*g) investigate the effects of a moving fluid such as air on objects located in it (8g);
h) conduct an investigation to illustrate Bernoulli's effect when a fluid flows through a constriction in a pipe such as a Venturi tube (8h).

4. Applications

a) The variation of pressure with depth in a fluid is taken into account in the design of dams, the design and safe use of underwater breathing equipment (scuba), and the design and use of aircraft breathing and pressurization systems.
b) Lift pumps and siphons operate because of the production of a difference in air pressure between the inlet and outlet sides of the pump or siphon.
c) Pascal's law applies to hydraulic systems, such as vehicle brakes and shock absorbers, hoists in a garage, hydraulic actuators, and the vascular system of mammals.
d) Water is conducted through the xylem in plants by capillary action.
e) Ships and submarines utilize Archimedes' principle.
f) The streamlining of vehicles, aircraft, and boats reduces the amount of energy needed to propel them.
g) A high-speed jet of water can be produced from a hose by reducing the area of the nozzle through which the water flows.
h) Because of their shape, pressure difference is produced on opposite sides of aircraft wings and hydrofoils when the fluid flows over one surface faster than it does over the other.

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*See the subsection entitled "Student Activities" on page 5.

i) An automobile carburetor and a jet water pump have a Venturi section, which creates a partial vacuum.
j) Hydraulics and pneumatics are used in control systems.
k) Atmospheric pressure variations are important in weather forecasting.
l) Vacuum cleaners produce a difference in pressure to draw in air.

5. Societal Implications

a) The great adventures of the last two decades have been the exploration of space and the depths of the sea. These accomplishments have been possible because of the application of knowledge of pressure to breathing systems and human physiology in high- and low-pressure environments.
b) Hydraulics and pneumatics have expanded the use of machines into applications where mechanical linkages are awkward and complicated.
c) The development of aircraft has opened up intercity and intercontinental travel to the point where few parts of the world are isolated.
d) The production and distribution of recreational sailing craft and aircraft are big industries.
e) There are many careers in pneumatics, hydraulics, and air and water transport.
f) Improvements in human health have occurred because of parallels drawn between hydraulic systems and the vascular system (e.g., valve control of blood flow).
g) The reduction of the surface tension of water by soaps and detergents permits inexpensive, easy cleaning, thereby promoting a high standard of hygiene.

6. Evaluation of Student Achievement

At least 50 per cent of the term mark for this unit is to be based on students':

a) laboratory work;
b) laboratory reports;
c) oral or written descriptions or labelled diagrams of the design and operation of devices that work because of a difference in pressure or the flow of a fluid.

7. Safety Considerations

a) If volatile fluids like alcohol are used, they should be kept away from flames, and their storage containers should be kept in a storage room.
b) If manometers are made of glass, students should be instructed on the safe handling of glass.
c) If a wind tunnel or fans are used as sources of flowing air, students should be cautioned about the danger of getting near their moving blades.
d) Students and teachers should not be exposed to open containers of mercury.
e) For further information on safety, teachers should refer to Part 1, section 9, of this guideline.

8. Possible Extensions

Some students might:

a) determine the density of different liquids so that pressure in a liquid can be related to density as well as depth;
b) construct and use a hydrometer to determine the relative densities of different liquids;
c) determine the buoyant forces acting on different objects in different liquids;
d) demonstrate, using simple models, the relative locations of the centre of gravity and the centre of buoyancy in ships and boats (include in the discussion the centre of effort on the sail of a sailboat);
e) relate fluid friction in pipes to the type of fluid and the diameter of the pipe;
f) report on aerodynamic drag on aircraft or hydrodynamic drag on watercraft and identify the variables that affect drag;
g) report on how a pitot tube is used in the determination of air speed in an aircraft;
h) "weigh" a car, using air pressure and area of contact of the car tires.

Optional Unit 2

Nuclear Energy

Time: 10 hours

Nuclear energy is used in the generation of a significant part of the electrical energy in Ontario and in Canada. Radioisotopes have become important in medical and industrial applications. Research in nuclear fusion may lead to a future energy source. At the present time no permanent solution has been found for the problem of nuclear waste. There is increasing resistance by the public to the construction of more nuclear power plants. For example, during 1988 a new nuclear power plant near New York City, built at a cost of five billion dollars, was closed before it ever started to operate because of the public's fear of a nuclear accident. Because of these developments students should understand the nature of nuclear reactions and of radioactivity. They will then be better able to understand the long-term issues associated with the use of nuclear energy and radioisotopes.

This unit may be divided into topics such as the following:

- Radioactivity
- Radioisotopes and their applications
- Nuclear reactions
- Nuclear reactors: CANDU
- Current issues in nuclear physics
- Careers in the nuclear industry

If a Geiger counter is operating when students enter the classroom for their first lesson on nuclear physics, their curiosity will be aroused. This is especially true if no radioactive source is being used, but the background radiation is being detected. Questions such as the following should provide some interesting discussion: What is this device? What is it measuring? What is it that makes it act as it does? A brainstorming session could follow this introductory demonstration to determine what students know and what misconceptions need to be cleared up. Students could do this brainstorming either in groups or as a class.

1. Objectives

Attitudes. Students will be encouraged to develop:

a) an appreciation for the benefits and risks associated with ionizing radiation and the need to guard against unnecessary exposure (3a-3c, 3g, 4a, 4d-4f);
b) an open-mindedness in evaluating the issues associated with the nuclear industry (3g, 4a, 4b, 4d, 4f);
c) an appreciation of the importance of employing suitable management techniques when dealing with nuclear wastes (3g, 4f).

Skills. Students will have the opportunity to develop skill in:

a) recording and organizing experimental data;
b) classifying materials according to shielding ability and radiation according to penetrating power;
c) constructing a graph illustrating radioactive decay over time and obtaining half-life information from it;
d) evaluating information in order to make decisions and value judgements (e.g., risk-benefit analyses);
e) surveying individuals in the community with regard to their opinion on current nuclear issues and summarizing these opinions in a report to be given either orally or in writing.

Knowledge. Students will be expected to:

a) describe several ways in which radiation can be detected and be aware of the symbol indicating radiation hazards;
b) describe how a radioactive substance differs from a non-radioactive substance;
c) name three types of radiation that could be emitted by a radioactive substance, compare their penetrating ability, and describe their effect on the human body;
d) define *isotope* and *half-life;*
e) describe three applications of radioactive isotopes;
f) explain the difference between nuclear fission and nuclear fusion;
g) describe the conditions under which a nuclear-fission chain reaction can occur;
h) name the major components common to all nuclear reactors and describe the function of each component;
i) explain how a nuclear reactor produces electricity, given a simplified diagram of such a reactor;
j) explain why the disposal of nuclear waste is a difficult problem to solve.

2. Teaching Suggestions

a) Old watches, older clocks with luminous dials, some types of smoke detectors, and dishes made with uranium dye (over half a century ago) are all radioactive and could be used as resources in the classroom.
b) Ontario Hydro has produced a wide range of resources that are available free of charge to teachers.
c) The public-relations departments of some nuclear power plants in Ontario employ individuals who are available to visit schools to discuss nuclear issues.
d) Back issues of many of the magazines found in school resource centres have articles on the Chernobyl and Three Mile Island accidents and other nuclear issues and advances.
e) By exposing photographic paper to radioactive sources, students will be able to see evidence of radiation like that seen by Becquerel.
f) Field trips to the nuclear medical facility of a hospital, nuclear power plants, colleges, universities, or industry would enable students to see nuclear physics in action.
g) Instead of a field trip for the whole class, several students could visit the places mentioned in 2f and prepare a report to be presented to the rest of the class.
h) Students could survey their neighbours to find out how they feel about nuclear power, nuclear waste, the use of radiation to preserve food, radon gas in homes, or other issues. An activity of this type would give students practice in preparing a questionnaire, interviewing people, and summarizing and reporting their findings.
i) Although many of the careers in the nuclear industry require a university degree and postsecondary work, there are some to which students in this course can aspire. They can, for example, become nurses, lab technologists in a nuclear facility, transporters of nuclear materials, and technicians in industry.
j) It is likely that someone in the class has a relative or acquaintance who has received treatment at a nuclear medicine facility. A brief report of this person's experience would be of interest to students.

3. Student Activities

Students are to:

*a) observe and describe tracks in a cloud chamber left by emissions from a radioactive source;
b) compare the penetrating power of alpha, beta, and gamma radiation through a given material;
*c) collect data from the radioactive decay of an isotope produced by a minigenerator, plot them on a graph, and determine the half-life of the isotope;
*d) label, on a diagram of a CANDU reactor, the major parts of the reactor and describe the function of each;
*e) determine the effect of distance from the source on the radiation received and plot a graph of distance against radioactive counts per unit of time;
f) determine the shielding capabilities of various materials;
g) prepare a report on a topic or an issue in nuclear physics, such as one of the following: nuclear waste; the use of radioisotopes; nuclear reactors (should more be built?); radiation and food preservation; attitudes of the community on nuclear issues and nuclear weapons; careers in the nuclear industry. These reports can be oral or written and may or may not involve the use of such supports as slides and videotapes.

4. Applications

a) Everyone working near radiation sources is required to wear an identification badge that contains radiation detectors in order to monitor exposure.
b) Radioactive isotopes are used as tracers and for medical diagnosis and treatment.
c) Radiation is used to kill micro-organisms, sterilize insects, and prevent the spoilage of food.
d) Nuclear fission is used as an energy source in the generation of electricity.
e) The properties of some materials (e.g., plastics, safety glass) have been enhanced by exposure to radiation.
f) Radioactive dating has been used to determine the age of relics, fossils, and the earth itself.
g) Nuclear-waste-disposal procedures must be designed to minimize the effects of radiation.
h) Nuclear fusion is the energy source of the sun and the stars.

5. Societal Implications

a) Radiation can produce mutations in reproductive cells with results that can be either beneficial or harmful.
b) Nuclear energy is an energy alternative in a time of rapidly diminishing fossil fuels, but one that requires a high initial investment of money.
c) The technology associated with nuclear energy has generated many new career opportunities in medicine and industry.
d) The nuclear industry has created situations in which the risks and benefits must be carefully examined and evaluated.

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*See the subsection entitled "Student Activities" on page 5.

e) Life expectancy has been increased partly because of the developments and advances in nuclear medicine.
f) Nuclear-waste management has generated and will continue to generate political debate.
g) Canada has made significant contributions in the fields of nuclear energy and nuclear technology.

6. Evaluation of Student Achievement

At least 50 per cent of the term mark for this unit should be based on students':

a) graphs and diagrams;
b) interpretations of the results of activities;
c) written answers or verbal reports based on reading assignments.

7. Safety Considerations

a) Radioactive samples should be handled and stored according to currently accepted practices.
b) For further information on safety, teachers should refer to Part 1, section 9, of this guideline.

8. Possible Extensions

Some students might:

a) investigate the characteristics, sources, and effects of other forms of radiation, such as X rays, cosmic rays, and ultraviolet radiation;
b) research radioactive-dating techniques;
c) present reports on the lives and work of scientists such as Becquerel, Curie, and Rutherford;
d) prepare reports on topics such as the following: nuclear weapons, nuclear accidents, breeder reactors, nuclear medicine;
e) investigate and describe the effect of a magnetic field on tracks in a cloud chamber;
f) calculate yearly radiation dosage for citizens in the local community;
g) prepare a report for presentation to the rest of the class on the Chernobyl or Three Mile Island accident, or on the use of nuclear weapons.

Optional Unit 3

Properties of Solids

Time: 10 hours

Whenever something is made, materials that are suitable for the intended use of the item must be chosen. The properties of materials to be considered include density, strength, hardness, elasticity, and thermal expansion. These characteristics influence the design of items, including their shape.

Much technological progress has come from the discovery and application of new materials, such as ceramics, plastics, and synthetic fibres. A wide variety of innovative and inexpensive goods has resulted.

This unit may be divided into topics such as the following:

- Hooke's law
- The elasticity of materials
- The strength of materials
- Structural strength and shape
- Centre of mass
- The density of solids
- The thermal expansion of solids

A beam or truss constructed out of wood or Bristol board can be used to introduce the unit. The beam should be supported at both ends. Students can be asked to predict how much mass is required to break the beam if masses are suspended from the middle of the beam. The student whose prediction is closest to the correct value can be rewarded with a bonus mark or some other incentive. While the beam is being tested, students can be told that the beam is deformed before it breaks and that for small masses this deformation is not permanent (if the mass is removed, the beam assumes its initial shape). Students can be informed that later in the unit they will be asked to design and construct a beam out of a specific amount of material and that it will be tested in the same way.

1. Objectives

Attitudes. Students will be encouraged to develop:

a) an appreciation of the need to test materials and products prior to their introduction or use (3b, 3d, 4b);
b) a curiosity about how materials are tested.

Skills. Students will have the opportunity to develop skill in:

a) observing and recording changes in materials under stress (2a-2d);
b) drawing charts and graphs to record experimental data (2a-2d);
c) using graphs to obtain information, such as a spring constant (2a-2d);
d) following instructions in conducting experiments (2);
e) controlling variables, such as the amount of bending with different structural shapes (2a-2d, 2g);
f) calculating the slopes of straight-line graphs (2a, 2c);
g) using calipers to measure the dimensions of objects (2f);
h) measuring volumes of irregular solids by the displacement of water (2f);
i) making simple calculations to determine the density of materials (2f).

Knowledge. Students will be expected to:

a) explain terms such as the following: elasticity, elastic limit, breaking point, shear, tensile, compression, torsion, stress and UTS (Ultimate Tensile Stress) (2a-2d);
b) state Hooke's law (2a);
c) describe changes in the shape of a material or in the assembly of a structure that will increase its load-bearing ability (2d);
d) define *centre of mass* and explain how it can be determined (2e);
e) describe the conditions that could cause an object such as a boat to roll over (2e);
f) define *density*;
g) explain the thermal expansion of solids and account for different rates of expansion for different materials (2g);
h) describe applications in which the specific physical properties of solids are used (2).

2. Some Teaching Suggestions

a) Different students should use springs and other materials with different elasticities in order to compare them.
b) Bridge and building designs can be demonstrated in the classroom through the use of films, videotapes, or a computer.
c) The sheet-metal shop, the woodworking shop, or the mechanical-drafting laboratory in the school or perhaps facilities in the local community could provide shaped metal or wood beams for student activity 3d. Students could specify the shapes they desire.
d) A variety of toys and other items are designed to operate with their centres of mass in unusual locations.
e) The centre of mass of a person can easily be found. A bathroom scale should be placed under each end of a plank. The individual then lies down on the plank and adjusts his/her position until the reading on the two scales is the same. The centre of mass of the person is then located at the centre of the plank. It is interesting to compare the centre of mass of females with that of males. This exercise could make an interesting addition to the investigation on centre of mass.
f) The class could take a field trip to a local industry where destructive testing occurs. Alternatively, several students can visit the industry and prepare a videotape or slide report of the testing procedure.
g) Students could examine local building codes to determine the requirements for structural supports in houses and garages. They could be asked to determine the minimum cost of supporting a specific structure, given the cost of lumber and the specifications of the local code.
h) A final exercise to complete the unit would be to have students work in groups to construct a truss from a given amount of material (e.g., a sheet of Bristol board or eighty popsicle sticks). The trusses could then be tested, by means of destructive testing, to see which one is the strongest.
i) One or more students could investigate the career opportunities that relate to this topic (e.g., carpenter, laboratory technician, masonry worker).

3. Student Activities

Students are to:

*a) measure the change in length of springs when they are subjected to different forces, graph applied force versus change in length, and determine the slope of the graph (6a, 8a);
*b) measure the change in length of various elastics, plastic bags, or other materials when more and more masses are suspended from or added to the item, perhaps to a breaking point; graph applied force versus change in length to compare the results; and compare the results with handbook data for different materials (6a, 8a);

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*See the subsection entitled "Student Activities" on page 5.

*c) observe and measure the bending in a metre stick or hacksaw blade clamped to the desk on one end and acted on by known forces at the other end, and graph the amount of bending measured against the applied force (6a, 8a);
*d) construct, out of sheet metal or Bristol board, beams of various shapes from identical strips of material; test the beams for structural stiffness and strength by measuring the amount of bend when they are subjected to known forces (one end clamped to the desk and masses applied to the overhanging part of the beam); graph the data obtained from this activity on one graph to show the relative strengths of each shape; and compare the bending of each beam with that of an unshaped strip of metal (6a, 8b, 8c);
*e) determine the centre of mass of various shapes by suspending these shapes from different points (8d);
*f) determine the volume of various materials, either from direct measurements (the use of calipers should be encouraged) or by the displacement of water, and determine the density of the material after its mass has been measured.

4. Applications

a) The elasticity of materials is the basis for measuring forces with spring scales.
b) The compressing, stretching, or twisting of materials past their elastic limit allows the shaping of objects such as car fenders and bumpers.
c) The structural strength of a beam is affected by its shape. For example, holes are cut into structural members of aircraft wings to make these parts lighter without sacrificing appreciable strength because the shape is not changed.
d) Load-bearing trusses and beams in bridges and walls have cross-bracing parts arranged to form triangles to resist deformation.
e) Synthetic fibres have aesthetic appeal, as well as great strength and elasticity. These properties make synthetic fibres suitable materials for clothing.
f) The soundproofing qualities of materials are related to density and elasticity. Denser, inelastic materials are better for soundproofing.
g) Expansion joints are built into structures such as bridges to allow for thermal expansion and contraction.

5. Societal Implications

a) Our standard of living is influenced by the availability of strong, yet relatively inexpensive materials for clothing, shelter, transportation, and communication.
b) The use of revolutionary construction materials or processes that make construction easier or goods more durable could have massive effects on employment and therefore the economy.

6. Evaluation of Student Achievement

At least 50 per cent of the term mark for this unit is to be based on students':

a) ability to measure accurately, using appropriate instruments;
b) laboratory records and reports;
c) preparation and interpretation of graphs;
d) ability to follow instructions for conducting activities.

7. Safety Considerations

a) Suspended masses should be affixed firmly, and protective materials placed below them so that no damage is done to the floor or the feet if a mass happens to fall.
b) If steam is generated and passed through hollow rods to show thermal expansion, the generating apparatus should be checked for proper assembly and operation.
c) A materials-testing apparatus should be used only under specified safe operating procedures.
d) For further information on safety, teachers should refer to Part 1, section 9, of this guideline.

8. Possible Extensions

Some students might:

a) investigate the effect of various cross-bracing designs on the rigidity and load-bearing capability of a structural design;
b) examine domes, arches, and flying buttresses in architectural designs to see how each design contributes to structural strength;
c) become involved in constructing models of buildings and bridges, which can then be compared for structural strength;
d) present a report on a topic such as the following: metal fatigue, geodesic structures and designs, prestressed concrete and some applications, non-destructive testing techniques, composite materials, the selection of appropriate materials for specific needs.

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*See the subsection entitled "Student Activities" on page 5.

Optional Unit 4

Locally Designed Unit

Time: 10 hours

This unit is to be designed at the local level as desired. It can be used to introduce a new area or topic of science not described in this guideline or to incorporate additional objectives that will expand a previous part or parts of the course. The following are examples of new areas or topics that might be considered:

- Basic astronomy
- Basic electronics
- Careers in physical science
- Colour
- Machines
- Physical properties of matter
- The physics of the human body

This unit may provide an excellent opportunity for students to engage in independent study on a topic in physics that is of particular interest to them. Students' work should be approved, monitored, and evaluated by the teacher. Students may work individually or in small groups. Care should be taken not to allow the work to overlap with subject matter in other science courses that students have taken or are likely to take. The unit could be started after students have had some experiences in the laboratory and are well aware of accident prevention. If a series of short topics is considered, such topics may be fitted into the program from time to time throughout the course.

A locally designed unit is to incorporate components similar to those adopted in the core units, namely, objectives, student activities, applications, and societal implications. A description of the unit is to be included with the school's course outline and kept on file so that it is available to interested students and parents.

Technological Science, Grade 12, General Level
(STE4G)

Core Units

Chemical Language and Calculations
Thermochemistry
Chemical Analysis
Kinematics
Statics
Kinetics

(97 hours)

Optional Units

Fluids
Machines
Materials
Locally Designed Unit

(12 hours)

Core Unit 1

Chemical Language and Calculations

Time: 16 hours

The purpose of this unit is to provide opportunities for students to use the language of chemistry. The application of this language by scientists, technologists, technicians, and manufacturers will be emphasized.

This unit may be divided into topics such as the following:

- Chemical names and formulas
- Combining capacity (valence)
- Writing and balancing chemical equations
- Atomic masses and formula masses
- The mole
- Chemical calculations

1. Objectives

Attitudes. Students will be encouraged to develop:

a) an appreciation of the global use of chemical language (3b);
b) an interest in the value of equations in predicting the quantities of raw materials needed (3a, 3b);
c) a curiosity about the chemical composition of everyday substances (3e, 4b);
d) a commitment to conserve materials (3d).

Skills. Students will have the opportunity to develop skill in:

a) writing formulas and naming binary compounds and compounds containing common anions (e.g., halides, oxides, sulphides, hydroxides, nitrates, sulphates, carbonates), cations (e.g., ammonium, alkali metals, alkaline earth metals), and several other elements, such as copper, iron, and aluminum (2);
b) calculating gram molecular masses and using these to calculate the number of moles or the mass of chemicals needed in a reaction (2);
c) calculating the number of moles, given the volume and concentration of a solution (2b);
d) balancing equations (2);
e) performing calculations involving chemical equations and chemical formulas (2);
f) handling apparatus and laboratory equipment correctly and safely (2);
g) measuring and recording experimental data accurately (2);
h) calculating a theoretical yield from a balanced chemical equation (2c, 2d).

Knowledge. Students will be expected to:

a) state the names and symbols of at least thirty elements (2, 8a);
b) state the meaning of *combining capacity (valence) of an element* (2, 8a);
c) write formulas for and state the names of binary compounds and compounds containing polyatomic ions, using valences and the periodic table for assistance (2, 8a);
d) demonstrate an ability to balance chemical equations (2);
e) define and give examples of each of the following: gram atomic mass, gram molecular mass, concentration, the mole (2);
f) use the mole concept to solve simple stoichiometric problems (2).

2. Student Activities

Students are to:

*a) carry out an experiment to determine the molar relationship between two substances, for example, placing an iron nail in a copper bromide solution or immersing solid copper in an aqueous solution of silver nitrate or performing a titration with an acid and a base of known concentration. This will emphasize the mole concept and provide a basis for writing equations (6a, 6b, 6d);

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*See the subsection entitled "Student Activities" on page 5.

*b) carry out an experiment to prepare a solution of given molar concentration and use this solution in a quantitative determination of the number of moles involved in a reaction (e.g., the reaction of iron and copper chloride) *or* prepare solutions of a given concentration and verify them by titration, using a standard solution (6a, 6b);

*c) perform an experiment to determine the experimental yield of a reaction in moles and by mass (e.g., the burning of magnesium or the heating of copper carbonate), calculate the theoretical yield for the reaction, and compare this to the actual yield (6c).

3. Applications

a) Chemical processes can be made more efficient as product yields are determined and profitability is predicted.

b) Equations are part of the language of chemists in communicating the reactants and products of reactions. Equations may be used to help explain many household and industrial processes.

c) The quality control of foods, drugs, and cosmetics is partly dependent on a knowledge of chemical reactions.

d) Valuable metals can be recovered from solution through the use of displacement reactions.

4. Societal Implications

a) Common or trade names for substances may not indicate details of their composition, whereas chemical names tend to be more meaningful. Different brand names may be used to sell the same chemical product at different prices.

b) Society must find safe means of disposing of some of the by-products of large-scale chemical reactions.

5. Evaluation of Student Achievement

At least 50 per cent of the term mark is to be based on students':

a) laboratory skills;

b) laboratory reports;

c) laboratory tests.

6. Safety Considerations

a) Students should be cautioned that many chemicals are harmful if not properly used. They should keep chemicals away from their mouths and eyes and should wash their hands after working with chemicals.

b) Students should tie back long hair and use safety goggles or glasses and aprons when appropriate.

c) Students should not look directly at burning magnesium.

d) Students should be taught to exercise care when handling silver nitrate, as it stains the skin.

e) For further information on safety, teachers should refer to Part 1, section 9, of this guideline.

7. Possible Extensions

Some students might:

a) prepare a compound by more than one method, calculating the experimental yield and comparing the yields for the different methods used;

b) do an analysis of class experimental data (e.g., an error analysis);

c) write a brief report on the value of balanced chemical equations to a chemical manufacturer;

d) write a brief report on the contribution of a chemist (e.g., Lavoisier, Dalton, Mendeleev, Curie, Pauling, Herzberg, Bartlett, Polanyi) to our present chemical knowledge or on a comparison between early and modern chemical processes.

8. Some Teaching Suggestions

a) As many elements and compounds as possible should be displayed when students are learning names, symbols, and valences.

b) Relevant films can be shown.

c) Students should be supplied with ion charts for tests and examinations. Understanding and use rather than rote memory should be emphasized.

d) This unit should be experimentally based. Its intent is to enable students to achieve skill in experimental work.

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*See the subsection entitled "Student Activities" on page 5.

Core Unit 2

Thermochemistry

Time: 16 hours

The purpose of this unit is to introduce students to a study of thermochemistry, its applications, and the impact of its applications.

This unit may be divided into topics such as the following:

- Temperature and heat
- Effects of heat on matter
- Heats of reaction
- Additivity of reaction heats and conservation of energy

1. Objectives

Attitudes. Students will be encouraged to develop:

a) an appreciation of the importance of heat energy in supplying the major energy requirements for our increasingly sophisticated technology;
b) a respect for the advances made in applying physical and chemical concepts and the impact that these applications have on society;
c) a commitment to conserve energy resources;
d) a respect for accuracy and precision in measurements (2a).

Skills. Students will have the opportunity to develop skill in:

a) measuring temperature and mass and calculating the specific heats of different substances (2a-2c);
b) determining the thermal expansion of various solids, liquids, and gases (2b, 2e);
c) deriving from experimental data the law of additivity of heats of reaction (2e);
d) classifying changes as physical, chemical, or nuclear and comparing the approximate energy changes that are involved (2d, 2e);
e) calculating heats of reaction, given standard heats of formation (2f).

Knowledge. Students will be expected to:

a) differentiate between temperature and quantity of heat (2a, 2c);
b) describe the construction and explain the operation of some temperature-measuring devices (2a);
c) compare and contrast the advantages and disadvantages of different types of thermometers and state their common uses (2a);
d) explain the following terms and give examples of each: linear, surface, and volumetric expansion (2b);
e) define the following: specific heat, exothermic and endothermic reactions, heat content (enthalpy) (2c-2e);
f) identify exothermic and endothermic reactions by their laboratory characteristics (2d);
g) identify a reaction as endothermic or exothermic from the heat of reaction (2f);
h) state and apply Hess's law and the law of conservation of energy (2e);
i) recall that energy is involved when bonds are broken or new bonds are formed (2e);
j) be aware of the relative amounts of energy involved in physical, chemical, and nuclear reactions (2e);
k) identify several careers associated with an understanding of thermochemistry.

2. Student Activities

Students are to:

a) measure accurately the temperature of different substances, using different kinds of temperature-measuring devices, such as a liquid-in-glass thermometer, a dial thermometer, a resistance thermometer, and a thermocouple thermometer;
b) measure the linear, surface, and volumetric expansion of some solids and liquids (6d);
*c) determine experimentally the specific heat capacity of various solids, using a calorimeter;
d) determine the energy effects of dissolving (both exothermic and endothermic), using, for example, sodium hydroxide and ammonium nitrate (6c);
*e) conduct simple experiments to derive Hess's law, such as the reaction between sodium hydroxide and hydrochloric acid (6c);

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*See the subsection entitled "Student Activities" on page 5.

*f) (i) determine heats of reaction from a standard heats-of-formation table; (ii) determine the quantity of heat, when given the quantity of the reactants and the heat of reaction; (iii) apply the energy-conservation formula (heat released = heat absorbed); (iv) determine temperature change for the calorimeter, when given the specific heat capacity and the mass of the calorimeter.

3. Applications

a) Gas thermometers are useful at very low temperatures. Dial thermometers are ideal for many industrial purposes. Resistance thermometers are well suited for measuring high temperatures (up to 1350°C) and are used for heat-treating and annealing processes in the metallurgical industry. The very small size of thermocouple thermometers make them convenient for determining accurately temperatures inside pipes, stacks, furnaces, and cylinder heads.

b) Allowance must be made for expansion and contraction in structures exposed to outside temperature variations (e.g., steel rails are laid with gaps between the ends to allow for expansion as a result of temperature changes, bridges are built on rollers or rockers, power lines are strung with a certain amount of slack, large masonry walls need vertical expansion joints filled with flexible caulking).

c) Changes of state are important in industry (e.g., in the refining of metals and petroleum).

d) The thermite reaction generates sufficient heat to raise the temperature of the iron produced above its melting temperature, before the heat is conducted away.

e) Electric-generating power plants use energy from physical, chemical, or nuclear reactions.

4. Societal Implications

a) The conservation of energy and the development of alternative energy sources such as solar energy will become even more important as supplies of conventional fossil fuels dwindle.

b) Houses and buildings of the future will feature innovative heating and cooling systems.

c) The use of heat energy has improved our lifestyle and is crucial to our personal as well as our technological survival.

d) Pollutants from heat engines pose serious health hazards and environmental problems.

e) The heat pollution of rivers and lakes is a cause for concern in some parts of the globe.

f) Energy supplies from fossil fuels are being depleted, resulting in the increasing dependency of industrial societies on nuclear energy. Thus, the acid rain problem may be replaced with the problem of where to store nuclear wastes.

g) The preservation of materials by the removal of heat has had a great impact on society (e.g., frozen foods, blood banks, seminal banks for livestock breeding).

5. Evaluation of Student Achievement

At least 50 per cent of the term mark for this unit is to be based on students':

a) experiments and laboratory reports;

b) practical laboratory tests.

6. Safety Considerations

a) The use of mercury thermometers should be avoided.

b) Students should take precautions when handling glass tubing and inserting thermometers into rubber stoppers.

c) Students should be given instructions in the use of solutions that may be poisonous, reactive, or corrosive. Students should keep liquids and solids away from their mouths, wash their hands after working with chemicals, and tie loose hair or clothing back.

d) Students should wear safety goggles when heating solutions.

e) The thermite reaction should be done only as a demonstration experiment.

f) For further information on safety, teachers should refer to Part 1, section 9, of this guideline.

7. Possible Extensions

Some students might:

a) research the use of optical pyrometers in measuring very high temperatures;

b) investigate the use of ultraviolet and infrared spectrophotometers and indicate the principles on which they are based;

c) demonstrate various experiments that indicate the anomalous behaviour of water;

d) perform experiments to show the different factors that affect the boiling point of a substance;

e) study the energy involved in fission and fusion reactions. Mention should be made of Einstein's relation of mass, energy, and velocity ($E = mc^2$);

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*See the subsection entitled "Student Activities" on page 5.

f) investigate how chemical hand-warmers function;
g) perform experiments to determine the heats of dilution;
h) compare and contrast the cooking of eggs and potatoes in microwave and conventional ovens;
i) investigate the significance of absolute zero and note some of the difficulties in attaining this temperature.

8. Some Teaching Suggestions

a) The activities used in this unit should be student-oriented. When the equipment available is limited, groups of students can be rotated around laboratory stations, each equipped for a particular activity.
b) The usefulness, accuracy, range, and span of each type of thermometer should be discussed.
c) Teachers should stress that it is important to indicate the states (solid, liquid, gas, or solution) of each reactant or product when writing chemical equations.
d) The phrase *heat content* may be preferred in place of *enthalpy*. Energy units in kilojoules are preferred.
e) Comparisons should be made of the magnitudes of energy released in physical, chemical, and nuclear reactions.

Core Unit 3

Chemical Analysis

Time: 17 hours

This unit makes students aware of some of the techniques of analytical chemistry and provides them with an opportunity to carry out laboratory activities aimed at solving "unknowns".

This unit may be divided into topics such as the following:

- Qualitative analysis
- Gravimetric analysis
- Analysing solutions
- Chromatographic analysis
- Instrumental analysis
- Careers in analytical chemistry

1. Objectives

Attitudes. Students will be encouraged to develop:

a) an appreciation of the usefulness of chemical analysis for quality control in all industries, including the food and pharmaceutical industries (3a, 3d, 3e, 4a, 4d);
b) an interest in the importance of chemical analysis in such areas of study as pollution control and forensic science (3b, 3c, 4b, 4d);
c) self-confidence in their analytical skills (2d, 2e);
d) the ability to analyse knowledge claims (8c);
e) a respect for accuracy and precision in measurement (3).

Skills. Students will have the opportunity to develop skill in:

a) following written and oral instructions to determine the presence and quantity of a substance in a given sample (2b-2e);
b) manipulating laboratory apparatus properly and safely (2b-2h);
c) determining the accuracy limitations of laboratory equipment (2b-2h);

d) summarizing observations in tabular form (2b-2h);
e) communicating laboratory findings effectively (2b-2h);
f) solving problems, using an investigative approach (2);
g) gaining familiarity with analytical procedures (2b-2h);
h) solving percentage-composition problems (2b-2d);
i) researching and writing reports on the careers involving chemical analysis (2a).

Knowledge. Students will be expected to:

a) define or state the meaning of the following: gravimetric, volumetric, chromatographic;
b) explain how a flow chart may be used to organize analytical methods (2b-2d);
c) distinguish between an observation and an inference (2b-2h, 8c);
d) use an analysis scheme to determine the presence or absence of substances in a sample (2b-2e);
e) explain how chemical and physical properties affect the type of analytical techniques used (2b-2h);
f) identify several careers that require a knowledge of chemical analysis (2a).

2. Student Activities

Students are to:

*a) prepare an oral or a written report, based on library research or interviews, outlining the wide range of careers involving chemical analysis;
b) analyse quantitatively a metal pollutant in water or a sample for a suspected contaminant (6a, 6b);
c) determine the iron content in certain food samples (6a, 6b);
*d) perform a gravimetric determination of copper, cobalt, nickel,or zinc (comparable experiments can be substituted, such as the determination of the percentage of phosphate ion present in a phosphate sample) (6a, 6b);
*e) carry out a volumetric analysis, such as the determination of the amount of vitamin C in several consumer products or the amount of calcium and magnesium in a milk sample (6a);
f) carry out a solvent extraction, such as the removal of iodine from a solution (6a, 6c);
g) determine the sulphur dioxide content of various foods (6a, 6b);
h) determine the mineral content in milk (6a, 6b).

3. Applications

a) The quality control of food, drugs, and cosmetics depends on chemical analysis.
b) The identification of substances in forensic science may help solve crimes.
c) Environmental studies rely on chemical analysis to identify pollutants and contaminants.
d) Chemical analysis is fundamental to many industrial processes (e.g., in the steel and oil industries).
e) Chemical analysis is the basis of the diagnosis of many diseases (e.g., urine analysis for diabetes mellitus).

4. Societal Implications

a) Without quality-control standards, based on chemical analysis, society would be subjected to products with widely varying degrees of purity.
b) Forensic scientists use chemical analysis in gathering and analysing evidence for criminal investigations.
c) The medical profession relies on many chemical analyses for accurate and rapid diagnoses.
d) Swimming areas and pools and drinking-water supplies are continually tested for contaminants.

5. Evaluation of Student Achievement

At least 50 per cent of the term mark for this unit is to be based on students':

a) laboratory skills;
b) laboratory reports;
c) laboratory tests;
d) library research (at least 10 per cent).

6. Safety Considerations

a) Students should be warned that many chemicals are harmful. They should keep chemicals away from their mouths and always wash their hands after working with chemicals.
b) Students should tie back long hair and use safety goggles and aprons.
c) Particular care must be taken with certain materials that might be used in this unit (e.g., iodine, nitric acid).
d) Care must be taken when open flames are used.
e) Precautions must be taken when distillation apparatus is used.
f) For further information on safety, teachers should refer to Part 1, section 9, of this guideline.

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*See the subsection entitled "Student Activities" on page 5.

7. Possible Extensions

Some students might:

a) visit a forensic science laboratory;
b) collect water samples from a number of sources and analyse them;
c) visit a quality-control laboratory;
d) investigate gas-liquid chromatography;
e) investigate various instruments used in analysis (e.g., equipment used to detect infrared and ultraviolet light or nuclear magnetic resonance);
f) supplement the solvent extraction of iodine from a solution activity by using a colorimeter and plotting an absorption curve;
g) collect and analyse air samples from a number of sources;
h) analyse a sample of tears.

8. Some Teaching Suggestions

a) This unit is based on student activities, and theoretical work should therefore be kept to a minimum.
b) A variety of problem-solving settings may be devised to increase interest and relevance (e.g., forensic case studies can be devised for most analysis activities, and Ontario ore samples can be used for metal analysis).
c) The emphasis should be placed on the development of correct laboratory techniques in arriving at accurate observations, measurements, and inferences, rather than on the understanding of the chemical reactions involved.
d) Evaluation should be based primarily on activities and laboratory work rather than written tests.
e) If equipment is limited, groups of students can be rotated around laboratory stations, each equipped for a particular activity.

Core Unit 4

Kinematics

Time: 16 hours

Kinematics is a study that breaks down the motion of a body into components so that it can be analysed. The study of machinery, transportation, or the everyday world is greatly enhanced by a knowledge of the fundamentals of kinematics. Modern robotics calls for a greater knowledge of kinematics than was previously required. With fast-moving machinery components, precision is essential; the study of kinematics demonstrates the need for precision.

This unit may be divided into topics such as the following:

- Kinematics equations
- Displacement
- Velocity
- Acceleration

1. Objectives

Attitudes. Students will be encouraged to develop:

a) an appreciation for the value of graphs and scale diagrams in illustrating motion and its results (3e);
b) a desire to measure precisely and record data accurately (3a, 3c-3e);
c) a respect for the validity of experimental data (3a, 3c, 4a).

Skills. Students will have the opportunity to develop skill in:

a) measuring the times and displacements of an object in motion (2a, 2d);
b) plotting displacement-time graphs and velocity-time graphs from experiments (2a);

c) determining velocity by calculating the slope of a displacement-time graph, both for a particular instant of time and for a given interval of time (2b);
d) determining average and instantaneous accelerations from velocity-time graphs (2b);
e) determining areas under velocity-time graphs of uniform and non-uniform motion to determine displacement (2b);
f) interpreting graphs of motion (2a, 2b);
g) solving uniform-acceleration problems, using the following kinematic equation: $a = \frac{v}{t}$;
h) representing vectors by directed line segments (2c, 2d);
i) drawing vector diagrams to determine resultant velocity and displacement (2c, 2d).

Knowledge. Students will be expected to:

a) know the meaning of the following: distance, displacement, speed, velocity, acceleration (2a-2d);
b) distinguish between (i) distance and displacement and (ii) speed and velocity (2a-2d);
c) distinguish between displacement and velocity in videotapes of motion (2a);
d) know the significance of the slopes and areas of graphs of motion (2b);
e) know the meaning of the following: uniform motion, accelerated motion (uniform and non-uniform), resultant displacement, resultant velocity (2a-2d);
f) describe the motion of an object from a displacement-time or velocity-time graph (2a, 2b);
g) select the proper kinematic equations to solve a problem involving uniform acceleration in a straight line.

2. Student Activities

Students are to:

*a) measure displacements over consecutive intervals for a non-uniformly as well as a uniformly accelerated object and plot displacement-time and velocity-time graphs from the data (2a-2c, 8a, 8c);
*b) analyse displacement-time graphs to determine velocities and velocity-time graphs to determine accelerations and displacements;
c) determine, on a map, the total distance travelled and resultant displacement, as well as average speed and velocity, for one or more designated trips by aircraft among three locations;
*d) construct a vector diagram to determine the resultant velocity of an object, such as an aircraft or a boat, affected by a wind or current;
e) use data obtained from a driver-education text or manual to plot a graph of stopping distances for an automobile against velocities and interpolate and extrapolate values, using the graph.

3. Applications

a) Consumer magazines often publish performance data on new automobiles, including acceleration rates and stopping distances.
b) A knowledge of kinematics is required in the design of acceleration lanes on superhighways and of airport runways.
c) The achieving of increased speed is an ongoing activity of racing-car builders and drivers.
d) A knowledge of kinematics is employed in the design and programming of industrial robots.
e) Pilots and sailors use vectors in plotting flight plans and making navigational adjustments.

4. Societal Implications

a) An understanding of the relationship between stopping distances and vehicle speed may influence driving habits.
b) Computers can produce graphs and charts from data for analyses.
c) The fascination of many people with speed has contributed to the popularity of automobile and speedboat racing.
d) The development of faster modes of transportation has created a global village.
e) The concepts of displacement, velocity, and time are integral to many daily activities.

5. Evaluation of Student Achievement

At least 50 per cent of the term mark for this unit is to be based on students':

a) laboratory skills;
b) laboratory reports;
c) laboratory tests.

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*See the subsection entitled "Student Activities" on page 5.

6. Safety Considerations

a) Any road tests to obtain data should be performed away from well-travelled roads.
b) Students should warm up before performing tests on bicycles.
c) Students should be told not to lean on air tracks and air tables.
d) All electrical equipment should have appropriate safety approval.
e) For further information on safety, teachers should refer to Part 1, section 9, of this guideline.

7. Possible Extensions

Some students might:

a) investigate angular motion or curvilinear motion and compare either or both to rectilinear motion;
b) investigate and report on the effects as the speed of an aircraft approaches and exceeds the speed of sound.

8. Some Teaching Suggestions

a) Students should be encouraged to use the number of significant digits appropriate to the measuring devices they employ when recording and using data.
b) Students should be encouraged to suggest improvements in the experiments that they conduct.
c) If possible, students should analyse realistic motion situations rather than performing pure laboratory experiments. This will increase their motivation.

Core Unit 5

Statics

Time: 12 hours

The purpose of this unit is to increase students' understanding of how and why structures remain stationary and stable in spite of the numerous forces that act on them. This study is termed *statics*.

This unit may be divided into topics such as the following:

- Characteristics of a force
- The vectorial representation of a force
- Resultant forces
- The resolution of forces into components
- Moments of forces
- The resultant of a parallel force system
- Free-body diagrams
- Reactions to a rigid body

1. Objectives

Attitudes. Students will be encouraged to develop:

a) an appreciation that force systems can be solved graphically, with sufficient precision for technical usefulness (3a);
b) an appreciation of the utility of statics in planning safe structures (3a, 4a, 4c);
c) an appreciation that graphic methods can provide a visual representation of a force system and save time in calculations (3a-3c).

Skills. Students will have the opportunity to develop skill in:

a) using appropriate scales in drawing force vectors (2b);
b) drawing a line parallel and perpendicular to a given line, using set squares and a pencil (2a);
c) resolving vectorially and graphically a given force into any two given directions perpendicular to each other (2a);

d) drawing a free-body diagram that represents the forces acting on a body (2b-2f);
e) determining the resultant of a parallel force system (2d-2f);
f) determining vectorially the resultant of two or more forces, using the rules of vector addition (2b);
g) reading a spring scale (2b-2d, 2g);
h) solving simple problems involving moments of force (2d-2f).

Knowledge. Students will be expected to:

a) know the relationship between the mass of an object and the force of gravity acting on it (2c);
b) describe, in a static situation, the magnitude, direction, and point of application of known forces (2b-2g);
c) represent known forces by suitable vectors (2b);
d) explain the terms *resultant* and *equilibrant* (2b-2g);
e) compare, in a static situation, the magnitude and direction of the resultant and equilibrant (2d-2g);
f) define *moment of a force* and *couple* (2d);
g) explain the principle of the transmissibility of a force (2g);
h) describe the relationship between the torque (or moment) and the distance of the force from the axis of rotation (2d-2f).

2. Student Activities

Students are to:

*a) draw lines parallel and perpendicular to a given line, using a 30°-60° set square and a 45° set square (8a, 8b);
*b) determine the resultant of two forces, using a force board; ascertain the direction of the resultant and equilibrant; and verify the resultant, using a graphical solution (8c);
*c) determine (i) the force of gravity acting on various masses, using a spring scale, and (ii) the gravitational-field constant near the surface of the earth;
d) investigate the principle of moments, using masses hung from a balanced rod or metre stick (6, 8d);
*e) for several loads suspended from a horizontal, rigid rod (i) find the single point from which the rod can be supported, (ii) determine the force required to support the loaded rod, and (iii) verify the magnitude and position of the supporting force mathematically *or*, alternatively, use a horizontally pivoted rod and apply the force horizontally to remove the force of gravity from the situation (6, 8e);
f) support a rigid rod by two spring scales attached to a frame; attach one or more loads to the rod at different positions and record the value on each spring scale; and verify these values mathematically (6);
g) compare the reading on a spring scale attached to a mass by a cord when (i) the mass is allowed to hang vertically, (ii) the scale is attached vertically to a rigid support and the cord and mass are hung over a pulley, and (iii) the scale is attached horizontally to a rigid support with the cord and mass over a pulley (6).

3. Applications

a) Statics is used to determine loads acting on structural members and on holding foundations.
b) The effects of the static loading of structural components are often determined by computer.
c) The principle of moments has been utilized in the design of many common mechanisms and machines.
d) An equal-arm balance operates on the principle of moments.

4. Societal Implications

a) The adherence to concepts of equilibrium in structural design prevents disasters.
b) Computer-assisted design allows several statics alternatives to be investigated when previously there might have been time to consider only one solution.
c) Many new variations in architecture in recent years can be attributed to a better understanding of the principles of statics.

5. Evaluation of Student Achievement

At least 50 per cent of the term mark for this unit is to be based on students':

a) laboratory skills;
b) laboratory reports;
c) laboratory tests;
d) library research (at least 10 per cent).

6. Safety Considerations

a) Students should be advised that the careful handling of equipment is necessary to prevent beams or masses from falling.
b) For further information on safety, teachers should refer to Part 1, section 9, of this guideline.

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*See the subsection entitled "Student Activities" on page 5.

7. Possible Extensions

Some students might:

a) investigate how a cantilever is supported so that it will not rotate out of position;
b) observe structures supported by guy wires and describe the forces acting on them;
c) solve mathematically vector problems dealing with finding resultants and components of forces;
d) investigate the conditions for equilibrium of a point.

8. Some Teaching Suggestions

a) Sufficient opportunities should be provided for students to become proficient in reading drafting scales and protractors, drawing lines parallel to a given line using set squares, and drawing free-body diagrams.
b) Sharp pencils rather than ball-point pens should be used for drawing.
c) Frames and force tables can be constructed from laboratory equipment or in school shops.
d) The principle of moments can be investigated by suspending a metre stick and moving masses attached to it to different positions along its length.
e) When determining the balance point of a metre stick with masses hanging from it, different student groups can be given different combinations of positions for the masses.

Core Unit 6

Kinetics

Time: 21 hours

Kinetics deals with force and motion. The concepts of force, work, energy, and power, arising from the study of kinetics, are vital building blocks of engineering technology.

This unit may be divided into topics such as the following:

- Newton's laws of motion
- The coefficient of friction
- Work and energy
- Power

1. Objectives

Attitudes. Students will be encouraged to develop:

a) an appreciation of the importance of experimentation in developing an understanding of physical phenomena;
b) an appreciation of the significance of the law of conservation of energy in the design and operation of any mechanism or machine (3, 4c).

Skills. Students will have the opportunity to develop skill in:

a) measuring the mass of an object (2b-2e);
b) measuring the force acting on an object, using a spring scale (2b-2d);
c) recording experimental observations accurately, such as those involving the acceleration of different objects subjected to various forces (2a-2f);
d) organizing experimental data in appropriate tables (2b, 2c);
e) controlling variables when investigating Newton's second law of motion (2b).

Knowledge. Students will be expected to:

a) state Newton's first law of motion and describe or explain situations where the law applies (2a);
b) express Newton's second law of motion as a formula (2b);
c) state Newton's third law of motion and describe or explain situations where the law applies (2d);
d) apply Newton's laws of motion to problems involving single and multiple forces (2a-2d);
e) define *normal force* and *coefficient of friction* (2e);
f) distinguish between static and kinetic friction (2e);
g) distinguish between potential and kinetic energy (2i);
h) state the formulas for calculating gravitational potential energy and kinetic energy (2h, 2i);
i) state the relationship between work done and energy transformed (2i, 2j);
j) state the law of conservation of energy and identify the energy transformations that occur in the operation of a specific mechanism or machine (2i, 2j);
k) define *power* and state a formula for calculating it (2j).

2. Student Activities

Students are to:

a) investigate several examples that illustrate Newton's first law of motion (6);
*b) investigate the relationships among force, mass, and acceleration (6, 8a, 8c, 8e);
*c) design and conduct an experiment to determine the acceleration resulting from gravity (6, 8a);
d) investigate several examples that illustrate Newton's third law of motion (6);
*e) determine the coefficient of static and kinetic friction for two surfaces in contact (8a);
f) solve problems involving objects on inclined planes;
g) determine the force needed to lift an object and calculate the work done as the object is lifted through a specific height (6, 8a);
h) investigate the relationship between the potential energy of a ball at the top of a ramp or grooved track and the kinetic energy that the ball has as it rolls off the track onto a desk top or the floor and explain the differences in values (8c, 8d, 8f);
i) solve problems involving the conservation of energy;
j) conduct an experiment to determine the power developed by a student or a machine performing a task.

3. Applications

a) The principles of kinetics are used in machine design (e.g., industrial robots).
b) The forces required to operate machinery can be reduced by designing components that are as light as possible while still strong enough to perform their functions (e.g., materials used to build rockets or lighter cars).
c) Pile drivers illustrate potential energy being transformed into work done. The same principle can be used to estimate the load that a given driven pile can support.
d) Wrecking balls transfer kinetic energy into work done.
e) Lubricating oils are used to reduce friction and the energy transferred to heat through friction.

4. Societal Implications

a) The use of seat belts in automobiles has been legislated in order to protect people during collisions.
b) The design of rides in amusement parks is based on the principles of kinetics.
c) Machinery is designed to employ the principles of kinetics as efficiently as possible in the completion of a task.
d) The conversion of non-renewable energy sources to heat is a major problem facing society.
e) The trend today is to produce more efficient machinery to reduce energy consumption.

5. Evaluation of Student Achievement

At least 50 per cent of the term mark for this unit is to be based on students':

a) laboratory skills;
b) laboratory reports;
c) laboratory tests.

6. Safety Considerations

a) Care should be taken with experiments involving the dropping of masses.
b) For further information on safety, teachers should refer to Part 1, section 9, of this guideline.

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*See the subsection entitled "Student Activities" on page 5.

7. Possible Extensions

Some students might:

a) compare the power ratings of automobiles and trucks from published reports;
b) build and launch model rockets;
c) construct and calibrate a spring balance to register force in newtons;
d) design, build, and test an elastic-propelled cart for energy efficiency.

8. Some Teaching Suggestions

a) Observations that include numerical data should be recorded in tabular form.
b) Students should be provided with opportunities to formulate conclusions based on their experiments.
c) Whenever possible, students should be provided with problems that reflect real-life situations that vary from fairly easy to very challenging.
d) Students should be encouraged to suggest improvements in the procedures for the experiments that they conduct.
e) Several different kinds of apparatus, such as an air-table and tape timers, could be used simultaneously by different groups to investigate Newton's second law of motion.
f) Plastic rulers can be used to make grooved tracks for energy-conversion experiments.
g) Students should not be required to memorize formulas; the emphasis should be on application.

Optional Unit 1

Fluids

Time: 12 hours

The purpose of this unit is to provide students with an opportunity to analyse and predict the behaviour of fluids at rest and in motion. The application of the unique properties of fluids will also be emphasized.

This unit may be divided into topics such as the following:

- Density of fluids
- Hydrostatic pressure
- Gauge pressure
- Archimedes' principle
- Streamlined flow
- Bernoulli's principle

1. Objectives

Attitudes. Students will be encouraged to develop:

a) a curiosity about the effects created by stationary fluids and fluids in motion (3d, 3e, 3g, 4a, 4b);
b) an appreciation for the contributions of Archimedes, Bernoulli, and Pascal to scientific development (3c, 3d, 3f, 3g, 4c);
c) an appreciation of the importance of fluids and their properties (3a, 4).

Skills. Students will have the opportunity to develop skill in:

a) measuring, calculating, and recording the mass, volume, density, and pressure of various liquids (2a-2h, 2k);
b) using a manometer to measure the relative hydrostatic pressures of fluids (2b, 2c);
c) mathematically solving problems involving pressure in a fluid, using the formula $p = gh$ (2b);

d) using a hydrometer to measure the relative density of a liquid (2h);
e) reading a mercury or aneroid barometer (2f);
f) recording and interpreting experimental results during the study of Archimedes' principle (2g);
g) drawing free-body diagrams of forces acting on objects completely or partly submerged in a fluid (2g);
h) observing and drawing diagrams to illustrate examples of streamlined and non-streamlined fluid flow (2i);
i) solving simple mathematical problems involving Pascal's law, gauge and absolute pressure, and Archimedes' principle (2d, 2e, 2g);
j) recording and interpreting the data for the pressure in the three regions of a Venturi tube (2k).

Knowledge. Students will be expected to:

a) recall mass, area, volume, density, and the SI units and symbols used to record them (2a, 2g, 2h);
b) define *pressure* as force per unit area measured in the SI unit pascals and having Pa as the SI unit symbol (2e, 2f);
c) explain the creation of pressure in situations involving liquids and gases at rest or in motion (2b, 2d, 2f, 2i, 2k);
d) explain how density and height affect hydrostatic pressure (2b);
e) state the relationship(s) among density, depth (height), and pressure in a fluid, that is, pressure = density x force of gravity x height (2b);
f) describe the relationship among the pressure, area, and shape of a container (2c);
g) explain how a barometer functions (2f);
h) give examples that illustrate Pascal's law and recognize and explain situations that involve its use, such as a fire hose under pressure or an inflated inner tube (2d);
i) differentiate among atmospheric pressure, gauge pressure, and absolute pressure and state the relationship among them (2e);
j) draw a diagram and explain the functioning of a hydraulic lever (2d);
k) state Archimedes' principle and use it to explain buoyant effects in fluids (2g);
l) differentiate between streamlined and non-streamlined fluid flow (2i);
m) identify factors that determine the drag produced on an object moving through a fluid (2j);
n) explain the variations in pressure seen in various locations of a Venturi tube as water flows through it (2k);
o) state Bernoulli's principle and explain applications of it (2k).

2. Student Activities

Students are to:

*a) measure the volume and mass of a given sample of a liquid and calculate its density (6a, 6b);
b) conduct an experiment to (i) compare the pressures at a specific height in fluids of different densities; (ii) compare the pressure in a fluid at different heights of the column; (iii) determine the effect of the height of a column of fluid on the pressure near the bottom (6a, 6b, 8a, 8b, 8e);
c) experimentally determine the relationship between the pressure and shape of a container with all other variables controlled;
d) verify experimentally Pascal's law (6c, 8b, 8c, 8f, 8g);
e) measure and record several gauge pressures and calculate the absolute pressure (6c, 8b, 8c);
*f) read the air pressure from an aneroid barometer for at least three consecutive days (6b, 8b);
*g) verify Archimedes' principle for suspended and floating objects (8b);
*h) determine the relative densities of several liquids, using a hydrometer (6a, 6b, 8b);
*i) investigate and draw diagrams of streamlined (laminar) and non-streamlined (turbulent) flow;
j) compare the time required for beads of different shape, size, and mass to fall through columns of liquids of differing densities (6b, 8b);
k) measure the relative pressure in a Venturi tube with a streamlined flow of water (i) downstream from the constriction, (ii) at the constriction, and (iii) upstream from the constriction (8b, 8c).

3. Applications

a) Fluids are the medium for transportation in a wide variety of systems, from intracellular systems to intercontinental flight (e.g., dissolved constituents enter and leave cells, fish swim in water, birds fly in air, human beings transport sound from mouth to ear through the medium of air).
b) Fluids act as lubricants to reduce friction (e.g., synovial fluid in joints, saliva in the throat, oil in hinges, grease between automobile parts).
c) Hydrometers are used to determine the quality of various fluids by measuring their relative density (e.g., the strength of battery acid or antifreeze).
d) Archimedes' principle helps to explain the operation of submarines and hot-air or weather balloons.

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*See the subsection entitled "Student Activities" on page 5.

e) Aircraft and motor vehicles are designed to reduce the drag of the air in order to increase fuel efficiency.
f) A hydraulic press is one universal application of Pascal's law.
g) A carburetor on a car and a spray atomizer employ Bernoulli's principle.

4. Societal Implications

a) Variations in atmospheric pressure contribute to different kinds of weather.
b) Pascal's law led to the development of many hydraulic devices, which reduced the need for much manual labour and permitted technological advances that were not possible before.

5. Evaluation of Student Achievement

At least 50 per cent of the term mark for this unit is to be based on students':

a) ability to carry out laboratory activities;
b) practical tests;
c) laboratory reports.

6. Safety Considerations

a) The use of mercury should be avoided.
b) Students should be informed of the particular hazards of each fluid used.
c) Students should be cautioned about the pressure differentials that can develop in some laboratory equipment, such as the hydraulic press.
d) For further information on safety, teachers should refer to Part 1, section 9, of this guideline.

7. Possible Extensions

Some students might:

a) design, carry out, and record observations in an experiment to determine the rate of flow of a fluid;
b) observe and analyse several experimental examples of applications of Bernoulli's principle, such as carburetors or Venturi meters (used in instrumentation and research);
c) examine the structure of various balls used in sports and analyse the reasons for their designs (size, shape, surface features such as bumps or pocks). Examples can include a golf ball, football, basketball, volleyball, tennis ball, squash ball, croquet ball, pool ball, billiard ball, and beach ball;
d) design siphons for various functions (e.g., an Archimedes screw for water elevation, a fountain pen for ink uptake, a gasoline siphon for negligent travellers, an aquarium siphon for cleaning the tank);
e) visit an auto shop, a garage, or an auto-assembly line and have a mechanic demonstrate and explain the operation of pistons, the measurement of oil pressure and tire pressure, and the operation of hydraulic lifts on trucks and farm machinery;
f) invite a cardiologist to speak to the class on pressure in the body's blood vessels and to demonstrate the measurement of blood pressure;
g) visit a steam or an agricultural museum or some other vehicle museum and report on the pressures and mechanisms involved in the operation of reciprocating and non-reciprocating steam engines;
h) use a pressure cooker to cook various foods, note the safety valve and timing variations needed for different foods (e.g., meat, fish, vegetables, fruits), and analyse the interrelationship between pressure and temperature in cooking foods;
i) derive and apply Torricelli's principle;
j) investigate the equipment that is used and instructions that must be followed for scuba diving because of the pressure under the water;
k) design and build a wind tunnel.

8. Some Teaching Suggestions

a) The value of understanding how and why pressure changes occur and what effects these changes have should be emphasized. It is the *pressure differential* that matters.
b) Before operating instruments or devices in this unit, students should examine the structures and make predictions regarding what will occur.
c) Gauges and devices foreign to students should be brought to class, and students should have the opportunity to predict how they might be used.
d) Guest speakers from industry and medicine can be invited to visit the classroom.
e) Students should construct their own manometers to be used in the activities.
f) Pascal's law can be investigated through the operation of a simple hydraulic lever.
g) A 2-m-long plastic tube of 10 mm in diameter and water with analine dye added can be used to demonstrate laminar and turbulent flow. Constant-velocity water flow should be examined first, followed by accelerated water flow. A ripple tank can also be adapted for this purpose.

Optional Unit 2

# Machines

Time: 12 hours

In this unit students will become aware that machines make work easier, save time, and are used to facilitate motion. The components of complex machines will be analysed.

This unit may be divided into topics such as the following:

- Simple machines
- Mechanical advantages: ideal and actual
- Pulley systems
- Efficiency
- Compound machines

1. Objectives

Attitudes. Students will be encouraged to develop:

a) an appreciation that machines help to make work easier (3b, 3d, 3f, 4b, 4c);
b) an appreciation that high-tech robotics still incorporates the concepts of simple machines (3e, 4b).

Skills. Students will have the opportunity to develop skill in:

a) classifying machines (2a, 2b);
b) rearranging components of machines (e.g., pulleys) to obtain optimum efficiency (2c, 2d);
c) calculating ideal mechanical advantage, actual mechanical advantage, and the efficiency of a machine (2a-2c);
d) measuring and recording forces and distances (2a-2c).

Knowledge. Students will be expected to:

a) identify the six simple machines (2a);
b) identify where the load and effort are applied for each of the six simple machines (2a-2c);
c) explain the value of machines to industry and workers (2);
d) define the following: ideal mechanical advantage, actual mechanical advantage, efficiency (2a-2c);
e) explain why the efficiency of machines is variable (2);
f) state the relationship between the ideal mechanical advantage and the number of strands in a pulley system (2c);
g) determine the ideal mechanical advantage of a compound machine (2c, 2d).

2. Student Activities

Students are to:

*a) determine experimentally the ideal mechanical advantage for each of the following: wheel and axle, inclined plane, wedge, screw jack (6, 8a, 8b, 8d, 8h);
*b) determine the ideal and actual mechanical advantage for a first-class lever for given load positions but different effort positions and compare the efficiency in each case (8a-8d);
c) assemble pulley systems to provide ideal mechanical advantages from 1 to 5 and determine the actual mechanical advantage and the efficiency of each (6, 8a-8d, 8h);
d) design and build a gear train to produce (i) a high speed of rotation and (ii) power, and determine the ideal mechanical advantage in each case (6, 8a-8d, 8h);
e) explain the different types of levers and the advantages of each;
f) explain single- and multiple-pulley systems and the advantages gained by each.

3. Applications

a) Levers and gear trains that have an ideal mechanical advantage of 1 are useful in instrumentation (e.g., Bourdon tube gauges, gas meters, clocks).
b) Levers are widely used in construction equipment (e.g., mobile cranes, backhoes).
c) Small worm-and-wheel mechanisms are useful for tuning guitars, for rack-and-pinion steering, and in a hand auger.
d) Motor-driven machinery utilizes gear or belt drives (e.g., rototiller).
e) Machines are so fundamental that they even have a place in space technology (e.g., the Canadarm).
f) Gear trains are used in multispeed racing bicycles.

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*See the subsection entitled "Student Activities" on page 5.

4. Societal Implications

a) The energy-supply problem has brought about the need for maximizing the efficiency of machinery.
b) High-tech machinery improves the quality of workmanship and reduces the number of tedious jobs.
c) By cutting down on the human energy required in the home or workplace, machines provide us with increased opportunities to participate in and enjoy leisure-time activities but also contribute to a decrease in the physical activity of many people.
d) The trend to manufacturing quieter machinery is sometimes hindered because the public associates noise with high power.

5. Evaluation of Student Achievement

At least 50 per cent of the term mark for this unit is to be based on students':

a) setting-up of machines as directed;
b) ability to perform the experiments and complete the calculations that are required.

6. Safety Considerations

a) Students should be warned that a small effort can cause great distress to a finger or hand at the output end of a machine (e.g., a screw vise).
b) For further information on safety, teachers should refer to Part 1, section 9, of this guideline.

7. Possible Extensions

Some students might:

a) collect pictures from periodicals and prepare a display of industrial or domestic machines that use simple machines as components (e.g., pictures of construction equipment that uses machines studied in class);
b) determine the efficiency of a commercial machine or mechanism;
c) use Mechano-type sets to build a variety of compound machines and analyse their characteristics;
d) investigate the human body as a machine.

8. Some Teaching Suggestions

a) Appropriate tables and graphs should be incorporated into laboratory reports.
b) All students should have hands-on experience with machines.
c) Experiments should be kept simple.
d) The accurate reading of instruments should be encouraged.
e) Students should be encouraged to bring to class examples of simple machines used in the home (e.g., kitchen gadgets, tools).
f) Students can visit museums of technology, bicycle shops, auto shops, and dockyards to observe a variety of machines.
g) Copies of appropriate periodicals should be available for student use.
h) To save time, various groups can each build one of the machines required in the different activities. The groups can then rotate through different stations to record measurements, or each group can work with one machine and report its results to the class for a general analysis.

Optional Unit 3

Materials

Time: 12 hours

The purpose of this unit is to provide students with an understanding of the properties and behaviours of materials so that they can use them in specific applications.

This unit may be divided into topics such as the following:

- Crystalline solids
- Cohesion and adhesion
- Stress and strain: extension and compression
- Density
- Hardness
- Corrosion
- Absorption of water
- Heat and electrical conductivity

1. Objectives

Attitudes. Students will be encouraged to develop:

a) a respect for the architects and engineers of the past and their contribution to our culture (3a, 4b, 4c);
b) an appreciation of the relationship between the properties of a material and its applications (3a-3c, 4c);
c) a curiosity about the composition of the structures and materials around them (3b, 3c, 3e, 4b);
d) an awareness of the use of new materials in construction and manufacturing (3a, 3c, 4c);
e) objectivity in analysing materials and structures (3b, 3c, 4b, 4c);
f) an appreciation of the impact that the development of many new synthetic materials has had (3a, 3c-3e, 4a, 4c, 4d).

Skills. Students will have the opportunity to develop skill in:

a) using a microscope (2a);
b) drawing sketches to record observations (2a);
c) measuring forces with a spring scale (2c-2e);
d) measuring distances and masses with appropriate measuring equipment (2e-2h, 2k);
e) calculating areas, stress, strain, density, Young's modulus, and the volume of a solid (2e-2g);
f) preparing samples of plaster of Paris and cement for use in the activities (2h, 2i);
g) following directions and recording observations for various activities (2);
h) drawing conclusions about the properties and behaviour of different materials (2b-2f, 2h-2l).

Knowledge. Students will be expected to:

a) describe properties that are common to all solids (2g);
b) distinguish between crystalline and amorphous solids and give examples of each (2a);
c) define the following: cohesion, adhesion, density, stress, strain, elasticity (2b-2h);
d) state the formulas for calculating Young's modulus and density (2e, 2g);
e) explain briefly the reasons for the cohesion and adhesion of materials (2b-2d);
f) describe how a metal can be protected from corrosion (2j);
g) describe the effect of too much and too little water in cement (2i);
h) explain how a geologist can determine which of two substances is harder (2h);
i) identify three substances that are good conductors of heat and two that are poor (2l);
j) identify two substances that are good electrical conductors and two that can act as insulators (2l);
k) explain the meaning of the terms *ductility* and *malleability*.

2. Student Activities

Students are to:

*a) observe and draw diagrams of samples of various crystalline solids as seen under a microscope, and observe and describe the crystallization of salol under a microscope or on an overhead projector (8a);
b) examine and compare the cohesion between different flat surfaces, including glass plates and plastic sheets (8b);

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*See the subsection entitled "Student Activities" on page 5.

c) compare the adhesion of different types of adhesive tapes to different surfaces. The tapes may be attached to a secured surface and a spring scale used to record the force needed to remove them (6b, 8c, 8d);
d) glue two pieces of wood or other material together, using different commercial adhesive products, and after the glue has set the recommended time, try to separate them, using a spring scale to record the force needed (6b, 8c, 8d);
e) determine the stress and strain on a given sample of wire or elastic fabric and calculate Young's modulus (6a, 8c);
*f) compare the stress and strain in compressing different samples of polyurethane foam, as well as samples of one type that have different surface areas (6a, 8c);
*g) identify a sample of metal or metal shot by determining its density (8c);
h) examine the hardness of various materials, such as plaster of Paris, cement, or different kinds of wood, by dropping on each, from a specific height, a vertically guided, hard-pointed bit. The shape and depth of the indentation produced should be described (6a, 8c, 8d);
*i) prepare small samples of cement, using correct and incorrect amounts of water, and after allowing each sample equal setting time as prescribed for the correct mixture, compare their characteristics (8d);
j) investigate the effect of oxygen, water, and salt on the corrosion of various metals (8c, 8d);
k) compare the ability of various substances, such as wood, brick, and cement, to absorb water by comparing the masses of samples before and after they are immersed in water for varying periods of time (8c, 8d);
l) compare the ability of different substances to conduct heat and electricity (6c, 8c).

3. Applications

a) The challenge of technology is to use materials wisely and to identify and fabricate imaginative and useful materials.
b) Many new adhesives have been developed (e.g., Crazy Glue) that are extremely strong and effective in small quantities.
c) Synthetic fibres are used in the production of fabrics for many purposes. These fabrics exhibit elastic properties, are light, and may be used in the clothing, furniture, and drapery industries.
d) The development of the space program has contributed many new materials for use in other fields.
e) Bridges, buildings, and vehicles can become unpredictably weaker as a result of stress reversals over a period of time and with changes in the seasons.
f) Synthetic materials are replacing metal parts on the exterior of automobiles.

4. Societal Implications

a) Since our natural resources are limited, their efficient use will not only save money but also provide for the future.
b) The strengths of materials change with the seasons and time. To ensure safety, it is necessary to conduct regular structural inspections of bridges, buildings, and aircraft.
c) New materials and innovative uses of presently known materials can improve the quality of the structures in our environment (e.g., the use of modern prestressed concrete in place of wood and steel).
d) Materials research and development is a growing area for career opportunities.

5. Evaluation of Student Achievement

At least 50 per cent of the term mark for this unit is to be based on students':

a) ability to carry out laboratory work and complete individual laboratory reports;
b) records of observations made during activities.

6. Safety Considerations

a) When testing the stress, strain, and hardness of materials, students should always protect their eyes with safety goggles.
b) During adhesion experiments springs and other materials can spring back or snap and damage eyes and other body parts. Students should be warned of these possible dangers.
c) The heating of materials can result in severe burns from both the heat and the materials. Students should be protectively dressed and be provided with suitable implements to grasp hot materials.
d) For further information on safety, teachers should refer to Part 1, section 9, of this guideline.

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*See the subsection entitled "Student Activities" on page 5.

7. Possible Extensions

Some students might:

a) investigate and report on the Moh hardness scale;
b) participate in a field trip to a local university or community college to observe the testing of various materials;
c) invite an engineer or architect to speak to the class on careers, the strength of materials, alloys, or another relevant topic;
d) visit a local steel, aluminum, nickel, or some other metal plant to observe first-hand the treatment of pure and alloyed metals;
e) research or test the strength of hollow (tubular) versus solid metal (cylindrical) materials under tension, compression, and torsion;
f) research the non-destructive testing of materials, such as ultrasonic testing for cracks in the landing gear of airplanes and the polarized testing of transparent materials;
g) view samples of the materials studied, such as cement and wood, under a microscope.

8. Some Teaching Suggestions

a) Students could view the materials studied under stereomicroscopes, if they are available.
b) "Static cling" should be discussed in relation to adhesion.
c) Time can be used efficiently in several activities if different groups work with different materials and then share their findings in order to draw general conclusions.
d) Students should have the opportunity to design experimental procedures and to select materials for study.

Optional Unit 4

Locally Designed Unit

Time: 12 hours

This unit is to be designed at the local level as desired. It can be used to introduce a new area or topic of science not described in this guideline or to incorporate additional objectives that will expand a previous part or parts of the course. The following are examples of new areas or topics that might be considered:

- Basic electronics
- Careers in technology
- Energy
- Machines

This unit may provide an excellent opportunity for students to engage in independent study on a topic in the technology area that is of particular interest to them. Students' work should be approved, monitored, and evaluated by the teacher. Students may work individually or in small groups. Care should be taken not to allow the work to overlap with subject matter in other science courses that students have taken or are likely to take. The unit could be started after students have had some experiences in the laboratory and are well aware of accident prevention. If a series of short topics is considered, such topics may be fitted into the program from time to time throughout the course.

A locally designed unit is to incorporate components similar to those adopted in the core units, namely, objectives, student activities, applications, and societal implications. A description of the unit is to be included with the school's course outline and kept on file so that it is available to interested students and parents.

Appendixes

Appendixes

A. Science Courses and Their Course Codes

B. The Table of Contents of Part 1

Appendix A

Science Courses and Their Course Codes

The secondary school guideline courses in science authorized under this document have the following course codes:

Science, Grade 9, Basic Level	SNC1B
Science, Grade 9, General Level	SNC1G
Science, Grade 9, Advanced Level	SNC1A
Science, Grade 10, Basic Level	SNC2B
Environmental Science, Grade 10, General Level	SEN2G
Science, Grade 10, General Level	SNC2G
Environmental Science, Grade 10, Advanced Level	SEN2A
Science, Grade 10, Advanced Level	SNC2A
Science, Grade 11, Basic Level	SNC3B
Applied Biology, Grade 11, General Level	SBA3G
Applied Chemistry, Grade 11, General Level	SCA3G
Environmental Science, Grade 11, General Level	SEN3G
Biology, Grade 11, Advanced Level	SBI3A
Chemistry, Grade 11, Advanced Level	SCH3A
Science, Grade 12, Basic Level	SNC4B
Environmental Science, Grade 12, General Level	SEN4G
Geology, Grade 12, General Level	SGE4G
Applied Physics, Grade 12, General Level	SPA4G
Environmental Science, Grade 12, Advanced Level	SEN4A
Geology, Grade 12, Advanced Level	SGE4A
Physics, Grade 12, Advanced Level	SPH4A
Technological Science, Grade 12, General Level	STE4G
Biology, OAC	SBI0A
Chemistry, OAC	SCH0A
Physics, OAC	SPH0A
Science in Society, OAC	SSO0A

The following general rules govern science course codes:

- All science course codes begin with an **S**.
- **SNC** identifies a course that has only the name "Science".
- Where one word other than "Science" describes the course, the first two letters of that word follow the **S** (e.g., **SBI** means "Science, Biology" or simply "Biology"; **SEN** means "Science, Environmental" or "Environmental Science").
- Where two words other than "Science" describe the course, the initial letters of those words are used (e.g., **SCA** means "Science, Chemistry Applied" or simply "Applied Chemistry").
- The fourth character in the course code, **1**, **2**, **3**, **4**, or **0**, represents Grade 9, 10, 11, 12, or an OAC respectively.
- The fifth character represents the level of difficulty: **B** for basic, **G** for general, or **A** for advanced.

For further information on course codes, refer to the *Manual for the Common Course Code* (Toronto: Ministry of Education, Ontario, 1986).

Appendix B

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Appendixes

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